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Smart Systems for Logistics Command and Control (SSLC2) Spiral One

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Interim Report for October 2003 to February 2006

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FOR THE COMMANDER

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DANIEL R. WALKER, Colonel, USAF
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14. ABSTRACT
Smart Systems for Logistics Command and Control (SSLC2) is an Air Force Research Laboratory, Warfighter Readiness Research Division, Logistics Readiness Branch program to develop and apply technologies to collect the critical information required to effectively manage logistics resources in support of combat operations. The purpose of SSLC2 is to develop requirements that employ technologies and techniques to autonomously collect and fuse critical data in order to create decision quality information and effectively present information to support cognitive tasks performed by logistics and operations decision-makers. SSLC2 Spiral One was focused on wing-level personnel concentrating on one primary decision, the fix/swap decision of an aircraft. The technologies developed under this spiral can be applied to many logistics and operations settings to include the Space ground asset management area. This report documents the efforts associated with the data collection, cognitive tasks analysis, storyboard development, and simulation test system development, along with the Scientific Study approach, methods, results, and recommendations.

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ABSTRACT

Smart Systems for Logistics Command and Control (SSLC2) is an Air Force Research Laboratory Warfighter Readiness Research Division program to develop and apply technologies to collect the critical information required to effectively manage logistics resources in support of combat operations. The purpose of SSLC2 is to develop capability requirements that employ technologies and techniques to autonomously collect and fuse critical data in order to create decision quality information and effectively present information to support cognitive tasks performed by logistics and operations decision-makers.

SSLC2 Spiral One was focused on wing-level personnel concentrating on one primary decision, the fix/swap decision of an aircraft. The technologies developed under this spiral can be applied to many logistics and operations settings to include the Space ground asset management area. This report documents the efforts associated with the data collection, cognitive tasks analysis, storyboard development, and simulation test system development, along with the Scientific Study approach, methods, results, and recommendations.

The Scientific Study was designed and conducted to validate the cognitive models developed from the data collection and cognitive task analysis and evaluate user performance and opinions on enhanced data streams demonstrated in the simulation test system. The study was conducted across four sites with each participant receiving all three conditions; SSLC2 simulated decision support capability, off-the-shelf technology condition called WhereNet that provides Radio Frequency Identification / Real Time Location System (RFID/RTLS) technology, and Baseline (status quo).

The study validated the hypotheses that participants would prefer SSLC2 over the other technology conditions along with validating the research objectives. SSLC2 was preferred over WhereNet and Baseline for monitoring and locating resources. SSLC2 was preferred over Baseline for identifying resource availability; SSLC2 was preferred over WhereNet for tracking time related to the movement of resources and for making the Fix/Swap decision. When participants rated their agreement with a variety of task statements there were significant differences between SSLC2 and Baseline but no

differences between SSLC2 and WhereNet. However, users commented that interaction with WhereNet was somewhat difficult. The results concluded the Cognitive Model was accurate and the field test verbal protocol results provided more detailed decision strategies.

Overall, the results show that SSLC2 must consider how enhanced data streams (such as location of resources) can be integrated with existing information to support user tasks and decisions within the context of their work. Location information as a stand alone system (WhereNet) was not preferred.

Detailed decision strategies and detailed decision impact information collected during the Scientific Study will be incorporated into the next Spiral to expand and cover more complex decision making. The next Spiral will also expand on the RFID/RTLS capabilities with enhanced sensor technology.

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1 Summary

The Air Force Research Laboratory Logistics Readiness Branch (AFRL/HEAL) contracted with the GRACAR Corporation to develop and apply technologies to collect the critical information required to effectively manage logistics resources in support of combat operations. Smart Systems for Logistics Command and Control (SSLC2) developed capability requirements that employ technologies and techniques to autonomously collect and fuse critical data in order to create decision quality information and effectively present information to support cognitive tasks performed by logistics and operations decision-makers.

Today's logistics and operational environment has little cross echelon situational awareness. Data capture and decision analysis are largely manual processes. Many of the current systems are standalone and do not share data. Personnel are often challenged when trying to locate the resources they need to perform their job. With many of the new technologies they can often be overwhelmed with too much data to effectively plan and allocate logistics resources. Personnel need a means to identify the impact of their logistics actions on operational capability. Often decisions are made to optimize resource utilization and not operational capability, such as sortie production.

Technologies such as Radio Frequency Identification / Real Time Location Systems (RFID/RTLS) and sensors improve situational awareness with respect to location and resource status. However, they do not provide insight into the whole operational capability. The decision making is still limited by the ability to assimilate the data into reasonable, actionable information.

SSLC2 utilizes the advances in smart sensors, computing technologies, information networks, and researches the human cognition and performance impacts from these advances. SSLC2 provides decision quality information fused from all of these enhanced data streams. Location and status data provides near time monitoring capability, while production and scheduling algorithms equate resource availability to operation capability and improved situational awareness. This provides decision makers insight into the operational impacts of their logistics decisions.

SSLC2 started the effort by first fully understanding the environment and the problem. A thorough literature search was performed and flightline personnel were interviewed across a number of Air Force sites (active, guard and reserve) using a variety of techniques. Knowledge representations were developed from the information to depict the processes and cognitive models. Storyboards were developed from information from these representations and data collected. Uses cases were developed to start the simulation test system development. The simulation test system was developed, reusing as much of Logistics Command & Information Support (LOCIS) as possible, tailoring to the SSLC2 field requirements [7].

A Scientific Study was designed and conducted to study the impacts of enhanced data streams provided by RFID/RTLS technology and fused data from legacy systems and potential future automated capabilities. The Scientific Study objectives were to:

1) Validate the cognitive model developed from data collection interviews through verbal protocol (source) techniques and to determine what information is most useful to help Expeditors make flightline decisions.

2) Evaluate user performance and opinions on enhanced data streams.

The Scientific Study compared three conditions. The SSLC2 condition integrated RFID/RTLS technology with flightline information for improved decision making. The off-the-shelf technology condition called WhereNet provided RFID/RTLS location of resources but did not integrate the information with the Expeditors work and decision processes. The Baseline condition was included as a control condition, allowing for comparison of the SSLC2 approach to current practice and enabling validation of the cognitive model.

The Scientific Study focused on the fix or swap decision construct identified in the data collection and cognitive task analysis processes. The verbal protocol technique was used to collect data related to the types of information and processes the Expeditors use to make their decisions. Participants were also asked to provide their opinions of the three conditions. The hypothesis was that participants would prefer the SSLC2 approach compared to the WhereNet off-the-shelf RFID/RTLS technology system. Because participants are so familiar with current practice and often resistant to change, it was

hypothesized that there would be no difference in preferences between the SSLC2 approach and the Baseline current practice approach.

The experimental design was a within-subject full factorial design. Each participant received all three conditions. Eighteen people volunteered to participate in the study. Participants were from the 445th Airlift Wing Air Force Reserve (AFRES) at Wright-Patterson Air Force Base (AFB), OH; 179th Airlift Wing at Mansfield Air National Guard (ANG), OH; 180th Fighter Wing at Toledo ANG, OH; and 122nd Fighter Wing at Ft. Wayne ANG, IN. Nine participants dealt with airlift aircraft, and nine participants handled primarily fighter aircraft.

The study was conducted by creating scenarios in which an aircraft on the flight schedule had a specific maintenance problem. The participant acting as an Expeditor analyzed the problem and determined whether to fix or swap the aircraft. Time would advance and the participant would monitor the flightline and have to assess and resolve future problems. Participants were given questionnaires to complete throughout the evaluation process. They were given a pre-test questionnaire, a post-condition questionnaire after completing each of the three experimental conditions, and a post-test questionnaire at the end of the study.

The post condition questionnaires addressed participants' assessment of each technology by asking them to rate their agreement on whether the technology provided support for monitoring of resources, locating resources, identifying resource availability, tracking time related to resources, usability, usefulness, impact on decision making (including the fix/swap decision), and situation awareness. When collapsing across all statements, participants rated SSLC2 to be better than Baseline. Seven specific statements showed significant differences among the three conditions, with all seven statements showing a difference between SSLC2 and Baseline. Four of the seven statements showed WhereNet to be better than Baseline. There was no difference between SSLC2 and WhereNet for these individual statements.

At the conclusion of the study, participants ranked their preference for the technologies. SSLC2 was ranked first and was significantly different than both WhereNet and Baseline rankings. WhereNet resulted in the lowest ranking; however, it was not statistically different from Baseline. Overall, when comparing SSCL2 to Baseline, 76%

of participants preferred SSLC2 for locating resources, 65% preferred SSLC2 for monitoring the status of resources, 70% preferred SSLC2 for tracking time associated with resources and 58% preferred it for making the fix/swap decision.

Post study questionnaires were also assessed for importance of certain information on decisions, how certain decisions impact a number of key maintenance metrics, and the importance of data elements that would be important in an electronic decision support tool. This information will be utilized for expansion to complex multiple decisions in Spiral Three.

A difference was discovered during field test in decision strategies between flightline airlift and fighter decision makers. Therefore, a portion of the verbal protocol not only assessed the data from an overall perspective, but also analyzed the differences between airlift and fighter results.

During the verbal protocol, participants were asked to think out loud during each scenario. The team documented all this information into process steps, with each step dissected into six categories, Information, Source, Destination, Decision, Time, and Process. The data from each of the categories were analyzed by frequency and by technology. These data were then analyzed as a whole to validate the Cognitive Model. The order of the process steps was then dissected by airlift and fighter and the differences analyzed. These results concluded the Cognitive Model was accurate and the field test verbal protocol results provided more detailed decision strategies. A cognitive task analysis was performed and more detailed knowledge representations were developed of their processes and cognitive models.

Throughout the study observations, suggestions, and feedback were documented. These included differences in decision strategies between airlift and fighter showing the benefits of conducting field tests at both types of sites. While the participants had numerous suggestions to changes to the graphical user interface they liked having both a geographic and schedule view for whichever situational condition level, flightline or aircraft problem, they were working. Participants supported the RFID/RTLS technology concepts and provided suggestions for the next steps with sensors and the information needed.

The next step for SSLC2 is to expand the research to investigate the impact of the sensor technologies when users are making multiple complex decisions on the flightline. All but one participant, a retiring supervisor, volunteered to be members of the SSLC2 Users Group and refine and expand the requirements for the next field test demonstration.

2 Introduction

Logistics support for the U.S. Military is a complex, time dependent, critical task. Creating Agile Combat Support (ACS) for the warfighter requires real time integrated information systems to support human decision making. Through the years, support tools have been created to support logistics problems. Many of the systems created have been standalone systems that do not share data. In the late 1960's the Logistics Composite Model (LCOM) was created to allow Air Force leadership to evaluate new weapon systems or modifications impacts on logistic resources and model for logistics manpower requirements [3]. Integrated Maintenance Information Systems (IMIS) was developed in the 1990's to integrate maintenance information such as technical manuals, diagnostic instructions, work orders, supply availability, etc in a single hand-held computer based integrated system [14]. In 1999, AFRL initiated the LOCIS program to research ways of utilizing existing data from current systems such as Core Automated Maintenance System (CAMS) and IMIS, and presenting the information to the Operations Group (OG) Commander, Logistics Group (LG) Commander, and their respective staff. The focus of the LOCIS program was on information fusion, decision support, and dynamic user interfaces [6, 7]. This successful program was a first step in developing integrated information systems to support human decision making.

The future vision is to develop SSLC2 to fuse large amounts of location and status information, provide situation assessment, and monitor equipment and human performance in such a way that human operators and technology work together as a symbiotic team. The warfighter requirement – the right information delivered at the right time at the right level.

Advances in smart sensors, computing technology, information networks, and research in human cognition and performance will help us move in this direction. Real-time sensing technologies can provide myriads of information to help support Air Force

logistics. For example, RFID technology is being used to improve In- Transit Visibility (ITV) of equipment and supplies during deployment [13]. RFID tagging is becoming standard within many commercial supply chains. The Autonomic Logistics System (ALS) is a concept to allow automatic detection of aircraft system faults or system deterioration to provide active logistics maintenance information versus the current reactive approach [5, 11]. War fighter physiologic and cognitive monitoring is being utilized to develop smart systems to adapt to the war fighters needs [8, 12].

AFRL is interested in incorporating real time sensing technologies to improve flightline logistics support. This technology, as well as others, has the potential to provide significant impact to flightline decisions. Although off-the-shelf RFID/RTLS technology provides immediate location information on tagged resources, and allows a decision maker to easily find these resources; in its stand alone form it is merely another information stovepipe. So while near real time information is available, it will not necessarily improve flightline decision making. The challenge with sensor technologies is to provide the correct information, at the right time, in the right format to improve human decisions and system performance. Too often, adding the technology without considering the impact creates "shelf-ware." Often development of new technologies, such as RFID, occurs so rapidly the technology push can lead to flawed technology-centric systems lacking a human centered engineering approach. In the end humans will be the ones using the technologies and systems to perform important tasks, make critical decisions and fulfill mission requirements. Human performance therefore must be central to system development.

With these considerations in mind the AFRL initiated the SSLC2 Advanced Technology Demonstration Program researching technologies and techniques, facilitated through software, to craft information enabling the warfighter to be more agile, productive and smart about critical logistic resources required for combat operations. It has been recognized that decision support tools must be created to fully exploit real time information. The SSLC2 program focuses on human performance in complex, time constrained, high-stress, decision making situations and on leveraging technology to assist the human decision-maker by capturing and displaying data in innovative ways to promote more effective decision making on the flightline. The overall goal is to provide

decision support on the flightline to improve sortie production resource allocation, personnel and resource scheduling, and decision making at multiple levels.

2.1 THE PROBLEM

Logistics and sortie production mission success depends on resources (people, equipment, and information). Yet few bases manage the availability and performance of their resources from a mission perspective. Resource management is often driven by priorities that are disconnected from the primary mission objectives and end-user requirements. Aerospace Ground Equipment (AGE), test equipment and people are employed in stovepipe fashion, leading to fragmentation and "silos" of infrastructure. This situation leaves managers with no visibility into overall service levels, no way to proactively detect and prevent availability and performance problems, and no means of quantifying the impact of downtime on the pilots, maintainers and the overall mission. It adds up to delays, complexity, over allocation and end-user frustration.

The problem is while there are intelligent, qualified people, equipment information including what resource is needed, the resource's related location, or its status is not always known. Equipment is used and returned to the ready line or the tool crib without any indication of a change in status. Sometimes equipment is used and then left in place for future known or unknown actions. The AGE driver is left to wonder if this equipment is still needed, ready for return to the ready line, or in need of servicing or repair. People of the same Air Force Specialty Code (AFSC) develop additional qualifications or higher levels of competency in various tasks, but that information is either documented in a manual record, somewhere in a wide variety of databases or, in the case of levels of competency, not documented at all. Many times decisions are made to optimize resource utilization, not sortie production.

To meet the demand for agile combat support a variety of information technology tools are being developed and purchased by the U.S. Air Force. Many of these off-the-shelf technologies are given to users and they are told to figure out how to use them. In many cases maintenance personnel are developing their own in-house programs to deal with the information they use. With the large amounts of information and complex

decisions that occur in the air base environment, it becomes crucial to involve users in the development of technologies, especially decision support tools, built for their use.

RFID and RTLS are examples of off-the-shelf technologies with potential to improve the maintenance process. RFID is sometimes called Dedicated Short Range Communication (DSRC). An RFID system, at a minimum, consists of three components: an antenna and transceiver (often combined into one component called a reader) and the tag, of which there are two types (passive and active). In a simple RFID system a passive tag is used along with a reader which is usually a permanent gateway into a facility. This will only allow for entry and departure readings from a defined facility or area. RTLS uses RFID technology to transmit the physical location of RFID tagged objects. RTLS systems require active RFID tags to be attached to each object needing tracked and Radio Frequency (RF) transmitters/receivers located throughout the facility determine the location and send information to a computerized tracking system. RFID/RTLS technologies with active tagging have the potential to improve awareness related to resource location by showing where things are. If the required piece of equipment is sitting on the flightline, it is not possible to tell, within the current applications, what it is doing out there. It might be in use, out of fuel, awaiting a high priority task to begin, or ready for re-assignment. These capabilities can be accomplished through customization of the off the shelf RFID/RTLS products.

These challenges reflect up to the Major Command (MAJCOM) and/or Air and Space Operations Center (AOC) in the broader context of "will that base meet its sortie schedule and support the mission?" and, "if not, what is the impact?" The characteristics of the current environment include little cross-echelon situational awareness due to a largely manual data capture and decision analysis processes. There remains very little insight to wing-level sortie production capability. Decision making is still limited by the ability to assimilate data into reasoned, actionable information. In the end, off-the-shelf Automatic Information Technologies (AIT) only solves a small part of the situational awareness and decision making challenge.

2.2 SSLC2 PROGRAM VISION

The vision of SSLC2 is to provide personnel decision quality information from multiple data streams including real time location and status data for monitoring capabilities, as well as algorithms to equate resource availability to operational capability. Decision-makers will be provided insight to the operational impact of their decisions. The SSLC2 effort is researching the fusion of technology with information to provide decision support and situational awareness aimed at demonstrating the capability for improved decision making that can affect sortie generation. The concepts are applicable across the AF spectrum and can easily be applied to functions such as civil engineering or transportation. Functional systems that support maintenance data collection along with developing systems that will contain electronic Technical Orders (TOs), Enhanced Maintenance Operations Center (EMOC) support systems, or even direct maintenance support systems would contain SSLC2 capabilities. In this way, predictive logic can be applied to determine the appropriate resources to use and maintain the highest possible Mission Capable (MC) rates. The SSLC2 vision incorporates Interface Requirements Agreements (IRA) with any system that collects data that would be useful in the management of people, equipment, and information. For example, if medical appointments are contained in a medical system, an IRA can be drafted allowing the extraction of data without violating the privacy of the medical system.

Another vision is that a system would contain job guides, the TO equivalent of a "How To" guide for major maintenance tasks on each weapon system. These job guides detail which major pieces of equipment are required and what follow-on maintenance is necessary. In this way, maintenance management functions can determine logical priority for task accomplishment with a maximized MC rate for the end product.

SSLC2 should continuously monitor all assets in its domain and report a variety of status indicators. Some of those indicators may be current operational condition (is it running), fuel load remaining, built in test status or perhaps data entered by the last user. This means maintenance managers will not only know what is needed for the job but they will, in one look, know where it is and if it is serviced, repaired and available; in short "it is the right resource for the job." If the resource is fully operational and ready for reuse,

the technician has only to put it back where it belongs or have the AGE driver pick it up. SSLC2 has already assessed and published its status.

Information about personnel resources, such as standard AFSC-related details, would be fused from the appropriate system and all AF Form 623 and Job Qualification Standard (JQS) data should be available. In addition, maintenance managers can make personal notes about workers to aid in selecting the correct person.

While the vision is to provide recommendations, the actual decisions and selections would be firmly in the hands of the maintenance manager. The goal of SSLC2 is to provide recommendations that optimize sortie production even if it appears that resources are sub-optimized.

Under the SSLC2 concept, not only will maintainers know where things are, they are provided recommendations as to which resource is most appropriate for the task at hand. No longer will the operationally oriented decisions be the sole domain of a few highly experienced airmen. While SSLC2 will not make the decisions for the maintainer, it will present all the information needed to make well informed decisions and recommendations.

Enhanced situational awareness provided by the SSLC2 concept can extend across command echelons and provide MAJCOM and Air Force Forces (AFFOR) decision-makers visibility into wing-level operational capabilities. They can look down into the operating locations and determine independently if the resources are in place to meet the flying schedule and Air Tasking Order (ATO). These decision makers can also quickly assess the impact of any degradation of sortie capacity.

SSLC2 is the logical conclusion to meet future needs of the Air Force. The SSLC2 research program is a key project toward facilitating informed decisions at multiple levels.

2.3 PROGRAM SCOPE

SSCL2 is a 6.3 Advanced Technology Demonstration (ATD) program researching ways to make the human warfighter more agile, productive and smart about the critical logistic resources required to support combat operations. SSLC2 is an effort to make existing systems "smarter" by utilizing data collection sensor technologies and fusing

data with existing information systems to improve Logistics Command and Control decision making. The program produces research, science and methods, and evaluates how existing technologies can be value-added enhancements to existing/forthcoming systems. The SSLC2 goal is to research, demonstrate, and position for transition, technology capabilities that can be applied to and integrated into existing systems to produce logistics-based operational capability awareness. The end product will identify requirements and demonstrate technologies that enable near real time monitoring of information on critical aspects of the logistics infrastructure. SSLC2 is not generating a new information system, but generating requirements and specifications that can be transitioned to an existing legacy system. Techniques and tools that can best enable logistics decision-makers to have a high-level view of logistics operations, identify potential problems, and make proactive decisions at various nodes within a logistics support environment must be identified and validated.

2.4 SSLC2 RELEVANCE TO AFRL/HE STRATEGIC GOALS

SSLC2 focuses on several of the AFRL/HE strategic goals and objectives, with the vision "Unleashing the power of human performance through technology" [2].

The Science and Technology Strategy is to "Develop, integrate, demonstrate, and transition affordable science and technology to meet warfighter needs." SSLC2 supports the strategic goal to enable improved decision effectiveness for all warfighters by providing task critical information portrayal, and decision support technology.

The Technology Value Strategy is to deliver the value of human effectiveness science and technology. SSLC2 supports multiple goals under this strategy including 1) Demonstrate value and educate stakeholders on the relevance of human effectiveness technologies; 2) Provide timely, objective, expert advice to decision makers; and 3) Collaborate with academia and industry to support Air Force needs and to transfer technology.

The Transformation Strategy is to enable the Air Force's transformation from platform-centric programs to development of effects-based combat capabilities. SSLC2 supports the goal to increase the directorate's capacity to meet current and future Air

Force transformational technology development needs and to expeditiously transfer technology.

2.5 PROGRAM SPIRALS

SSCL2 is broken into three spirals. This report details the outcome of Spiral One. This section briefly describes each of the three spirals.

2.5.1 Spiral One

Spiral One provides Technology Availability Date (TAD) 1, for Autonomous Data Collection of Logistics Resource Information. This spiral focused on the Expeditor's work processes. Expeditors must make decisions to allocate resources to keep aircraft maintained and operational to meet operational flying schedules (Figure 1). The resources (e.g. equipment and personnel) may be available within their own maintenance units, or resources may be borrowed from another aircraft maintenance unit. It is a challenge to track resources and schedule information, and determine the impacts of their decisions during oftentimes hectic flightline operations. In the current process, information gathering is manual and paper-based; while computer supported decision analysis tools are minimal to nonexistent. Decisions are often made quickly to solve the immediate problem, with little thought to optimizing resource utilization and sortie production. Personnel can be overwhelmed by multiple tasks, frequent interrupts, and the need to mentally integrate information from a variety of sources making it difficult to effectively plan and allocate logistics resources.

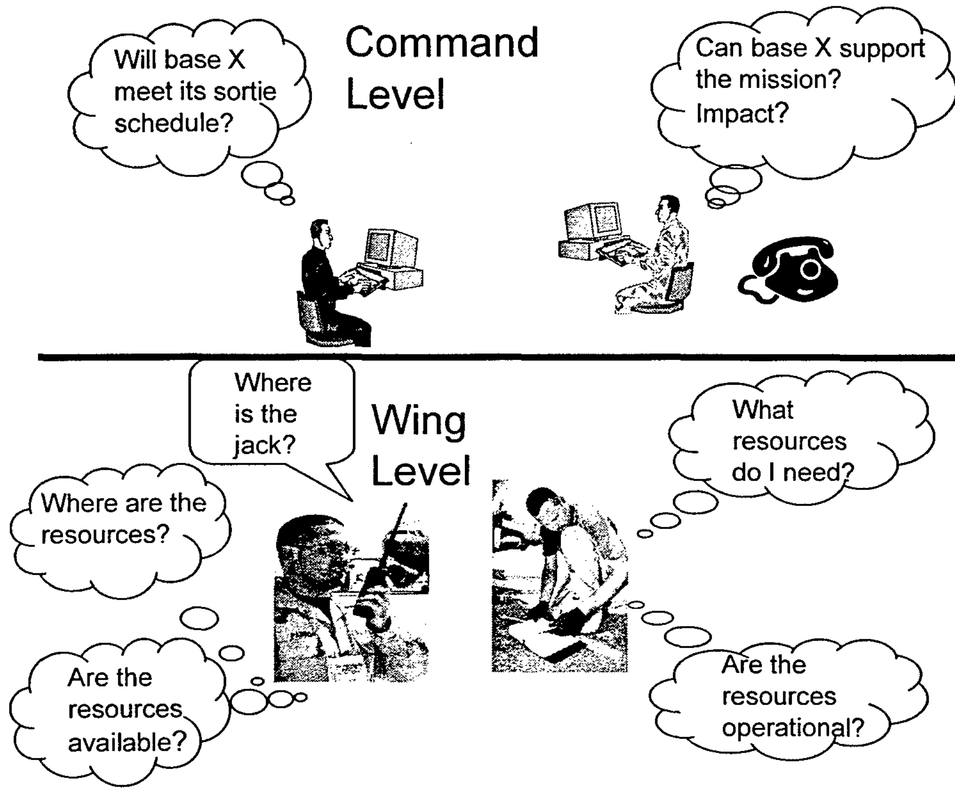


FIGURE 1: CHARACTERISTICS OF THE CURRENT ENVIRONMENT

A cognitive task analysis was performed and a cognitive model developed of the Expeditor to understand the task domain and user needs. To successfully and smoothly integrate autonomous data collection and decision support tools for the Expeditor it was necessary to understand the Expeditor task domain. Data were collected from a variety of sources and the process and results are described in Section 3.1.

The autonomous data collection system investigated in this spiral is RFID/RTLS technology for the purpose of providing enhanced data streams. For this spiral, an RFID/RTLS system was simulated to tag flightline resources and provide the Expeditor visibility into those resources when making flightline decisions

There were two primary research objectives in this Spiral:

Objective 1: Validate the cognitive model developed from data collection during a Scientific Study. The purpose of this objective was to ensure the cognitive model preliminary decision construct (model) was accurate. The Scientific Study and results that describe the outcome of this objective is presented in Section 5.7.1.

Objective 2: Evaluate user performance and opinions on enhanced data streams. A Scientific Study was conducted to determine 1) if users are better able to locate and estimate the time it takes to get all the resources to the fix site, and 2) if users prefer the SSCL2 integrated information approach to off-the-shelf RFID/RTLS and current practice. The Scientific Study and results that describe the outcome of this objective is presented in Section 5.7.2.

2.5.2 Spiral Two

The Spiral Two, TAD 2, Decision Improvement for SSCL2 will focus primarily on the Space customer and therefore, will not be addressed in this report.

2.5.3 Spiral Three

Spiral Three, TAD 3, is Integration and Collaboration and expands on the Spiral One concepts by not only supporting the Expeditor making the fix/swap decision, but also managing their flightline and flying schedule and having insight into the impacts of their decisions and resource utilization on the flying schedule. Long range sensor tags will be added and a site will be outfitted with a RTLS infrastructure. The research objectives for this Spiral focus on whether enhanced data streams impact complex multiple decisions.

Spiral Three, will demonstrate and measure key performance parameters supporting this research objective. Can they identify and make their critical decisions in less time? Do the SSLC2 visualization techniques improve their decision making process? Does SSLC2 improve the timeliness of status information? Spiral Three will also look at impacts to global and local situational awareness.

2.6 DOCUMENT OVERVIEW

The Spiral One Final Report presents the main activities associated with the SSLC2 program highlighting the research approach and objectives used to gain insight into the cognitive model of maintenance Expeditors and to evaluate the effects of enhanced data streams using RFID/RTLS technology on flightline decision making. The report is organized into sections describing the various research activities of data collection, design, development, and data analysis performed during Spiral One. Figure 2 illustrates the main components of the report. Section 3 presents the Spiral One Methods and Approach including data collection and storyboarding, software architecture, and the

cognitive task analysis activities used to develop the Scientific Study. Section 4 describes the Scientific Study approach. Section 5 presents Scientific Study analysis and observations. Section 6 presents Recommendations which includes future requirements and considerations followed by conclusions.

Appendices are attached to this report to further illustrate the work accomplished to reach Spiral One goals. Appendix A defines Acronyms used in this report. Data Collection (Appendix B) and Scenarios (Appendix C) highlight work done with Subject Matters Experts to better understand the flightline environment.

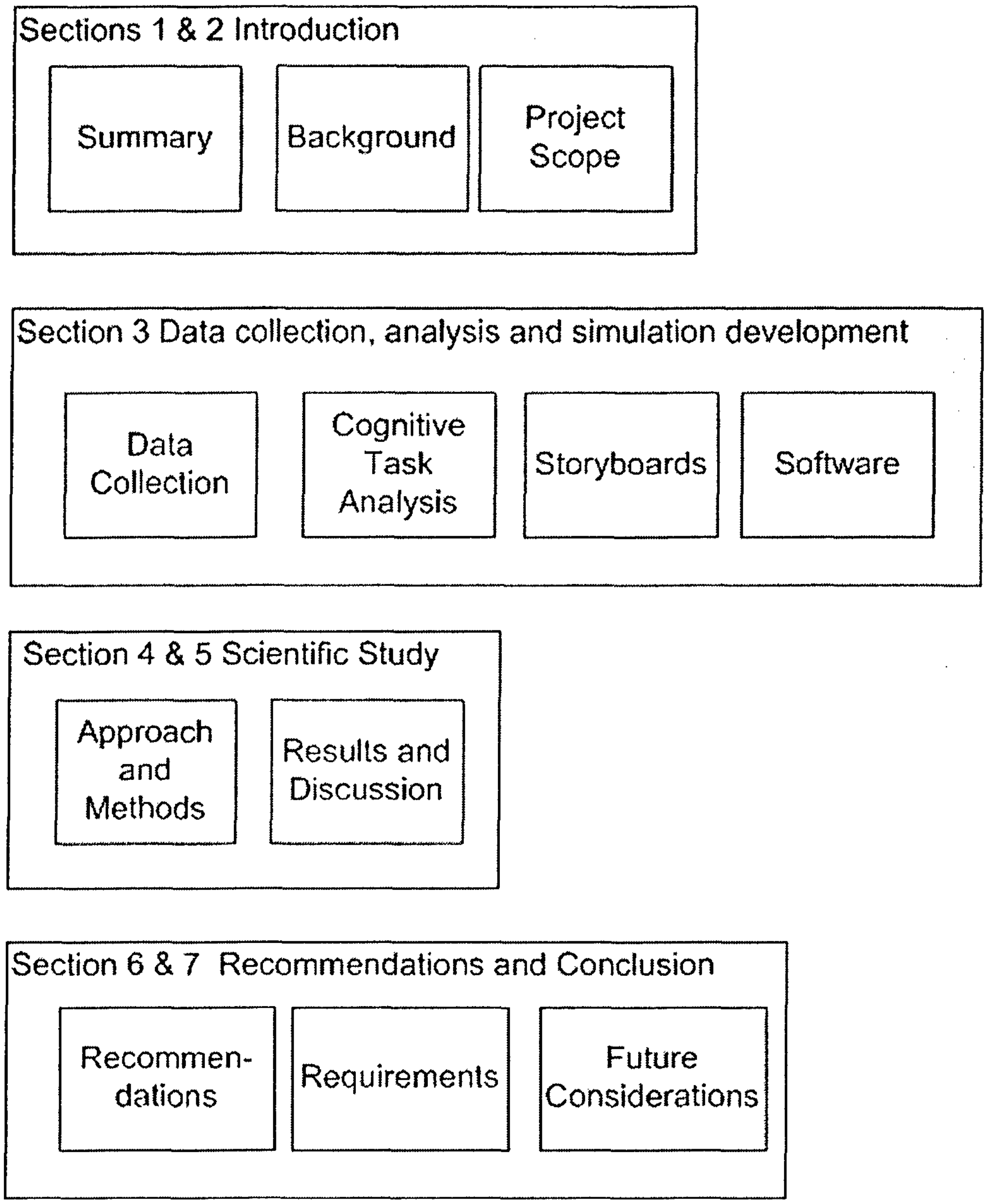


FIGURE 2: DOCUMENT OVERVIEW

3 Spiral One Methods and Approach (Data collection, analysis, and simulation development)

There were two primary research objectives in this Spiral as outlined in Section 2.5.1. To meet these objectives a systematic research process was followed which is illustrated in Figure 3 and described below.

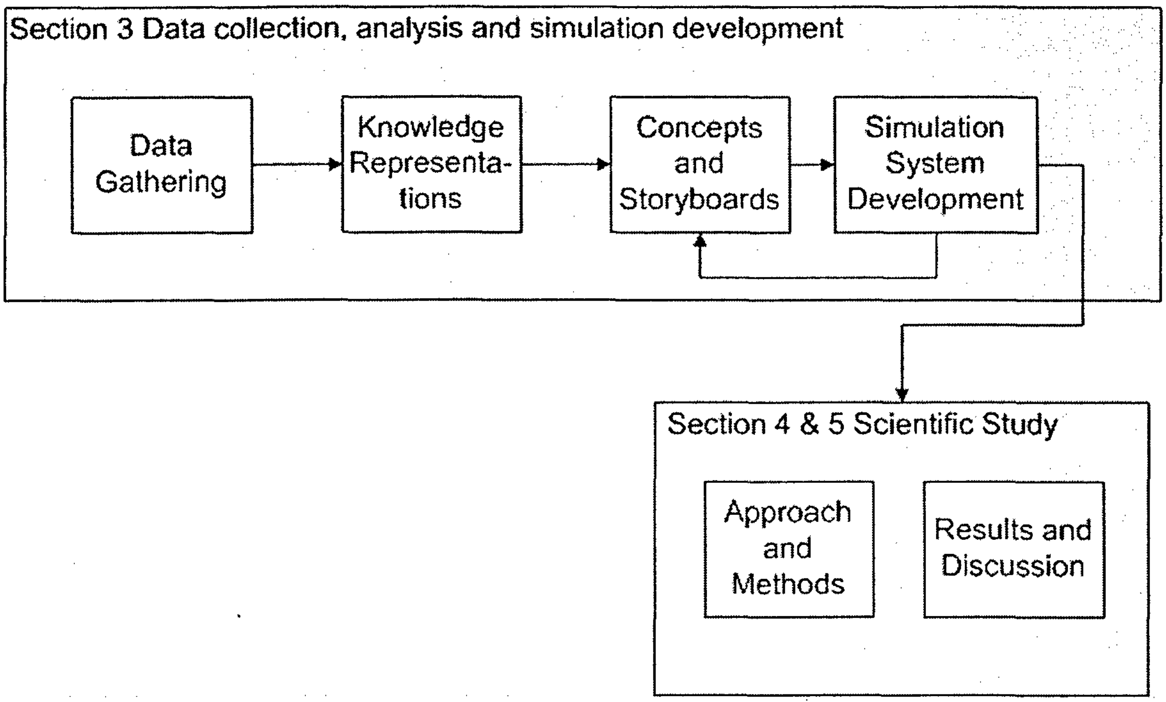


FIGURE 3: SSLC2 RESEARCH APPROACH

1. The first step was to perform a systems analysis focusing on the flightline wing maintenance process within the overall sortie generation process with a primary focus on the role of the Expeditor. During this step data were collected from subject matter experts (SMEs) at a variety of Air Force sites.
2. The second step was to compile the data collected in Step 1 into representations of the information including a cognitive model of Expeditor tasks.
3. The third step was to develop concepts and storyboards that could be used to develop a simulation to allow testing of SSLC2 concepts for enhanced data streams.
4. The fourth step was to develop the software for the simulation test system.

This section provides details and findings for each of the four steps described above. Upon completion of these steps a Scientific Study was designed and conducted to validate the cognitive model (Objective 1) and evaluate the enhanced data streams (Objective 2). The Scientific Study is described in Section 4.

3.1 SYSTEMS ANALYSIS AND DATA COLLECTION

Data collection efforts focused on gathering information relevant to enhancing information streams coming to flightline decision makers. While these data gathering activities focused primarily on preparation for Spiral One, data relevant to the entire SSLC2 program were collected. Cross-functional data collection teams including researchers, analysts and subject matter experts collaborated on material preparation, participant visits, interviews, and note compilation. When interviews were conducted, a small cross-functional team of two to three people were assigned to each interviewee. Depending on the number of interviews scheduled for the site and the time allotted, the number of small teams would fluctuate.

Participants in the data collection activities were asked to volunteer approximately 1½ hours of their time. The range of personnel was very broad. Personnel interviewed included Production Superintendents (ProSuper), Expeditors, Maintenance Operation Center (MOC) controllers, AGE supervisors, AGE dispatchers, AGE drivers, Fuels drivers, Fuels Supervisors, Deployment Managers, and Logistics Group Commanders.

Data were collected from several sites. Each site provided extremely valuable information for the overall capabilities of the Spiral One SSLC2 demonstration. Initially, a trip was made to the Air Force Special Operations Command (AFSOC) at Hurlburt Field, FL. This trip provided initial information regarding resource allocation processes at a high operational tempo, regular Air Force, heavy aircraft facility. A data collection trip was made to Luke AFB, AZ, which is a high operational tempo regular Air Force facility with fighter aircraft. Luke AFB is one of the Air Force's largest sortie production bases, with its training missions.

In addition to the regular Air Force sites, Air National Guard and AF Reserve Command facilities were also a major part of the data collection activities. Due to the close proximity of the 445th Wing at Wright-Patterson AFB, and the Ohio Air National Guard base at Springfield, Ohio, these sites were visited on several occasions to collect and verify information gathered. These sites provided not only the full perspective of Air Force capabilities with regard to flightline resource allocation and usage; they also provided extremely experienced personnel with deep knowledge of Air Force logistics challenges. Along with regular Air Force installations, they represent the full wartime

capability of the Air Force's Joint Force Concept (i.e., the wartime Air Force is comprised of regular, guard and reserve personnel).

Other data collection sites were visited as opportunities presented themselves. For example, a trip was made to Headquarters Air Force Materiel Command (HQ AFMC) which assisted in identifying the informational requirements associated with deployment activities. Additionally, several meetings were held with the Air Force Research Laboratory's Information Visualization (AFRL/HECV) specialists for the purpose of collaborating on programs, and leveraging research methods and results across programs.

Methods used for data collection included several techniques including process interviews, personnel shadowing, cognitive walkthroughs, team interviews, and a concept mapping interview. A primary focus of the interviews was to understand difficult or complex decisions made with regard to flightline resource allocation and usage and decision process and information used for the fix/swap decision. Table 1 identifies the locations, positions interviewed, and types of data collection methods used at each site.

TABLE 1: DATA COLLECTION SITES AND ACTIVITIES

	Hurlburt Field	WPAFB HQ AFMC	AFRL/ HECV	WPAFB	Springfield OANG	Luke AFB
MOC				Process	Process	Process
Mx (Expeditors, ProSupers)				Process	Process	Shadowed, Process, Cognitive Interviews
AGE (Dispatchers, Supervisors, Drivers)	Process			Process, Cognitive Interviews	Process Cognitive Interviews	Shadowed, Process, Cognitive Interviews
Fuel (Drivers, Supervisors)	Process					Shadowed, Process, Cognitive Interviews
Deployment Managers		Informal Team Interview		Process, Cognitive Interviews		Process, Cognitive Interviews
Researchers			Informal Team Interview	Concept Mapping		

3.2 KNOWLEDGE REPRESENTATIONS

Four knowledge representations were generated from the data collected: 1) Flow chart and description for flightline maintenance process, 2) Concept Mapping of an Expeditor, 3) Hierarchical Task Analysis; and 4) Operator Function Model (OFM) supplemented with COGnitive information (OFM-COG). Each is described below.

3.2.1 Flightline Maintenance Process Overview

Figure 4 is a basic flow diagram illustrating the overall flight maintenance process. The initiation of the maintenance process differs depending on whether the unit is operating under AOC direction or operating under training guidelines. Sortie generation is an iterative process and there is no clear beginning or ending point. Maintainers generally consider the start of the actual generation of the day's sorties as the beginning of the process, but it would be just as appropriate to deem it to begin as the aircraft return from the day's last flight. These landing aircraft become the basis for planning the next day's flying schedule based on their maintenance status.

When aircraft return from a mission the aircrew identifies the aircraft maintenance status code (AKA a "Squawk"). A Code 1 squawk equates to a Fully Mission Capable (FMC) aircraft. Code 2 indicates a flyable aircraft but some system has a problem; a Code 2 aircraft may be FMC. Code 3 indicates an aircraft with a non flyable condition. Code 2 or 3 squawks usually include verbal information indicating which aircraft system has a problem. For example, a squawk of "Code 3 hydraulics" would indicate a major fault with the hydraulic system that will ground the aircraft until repairs are made.

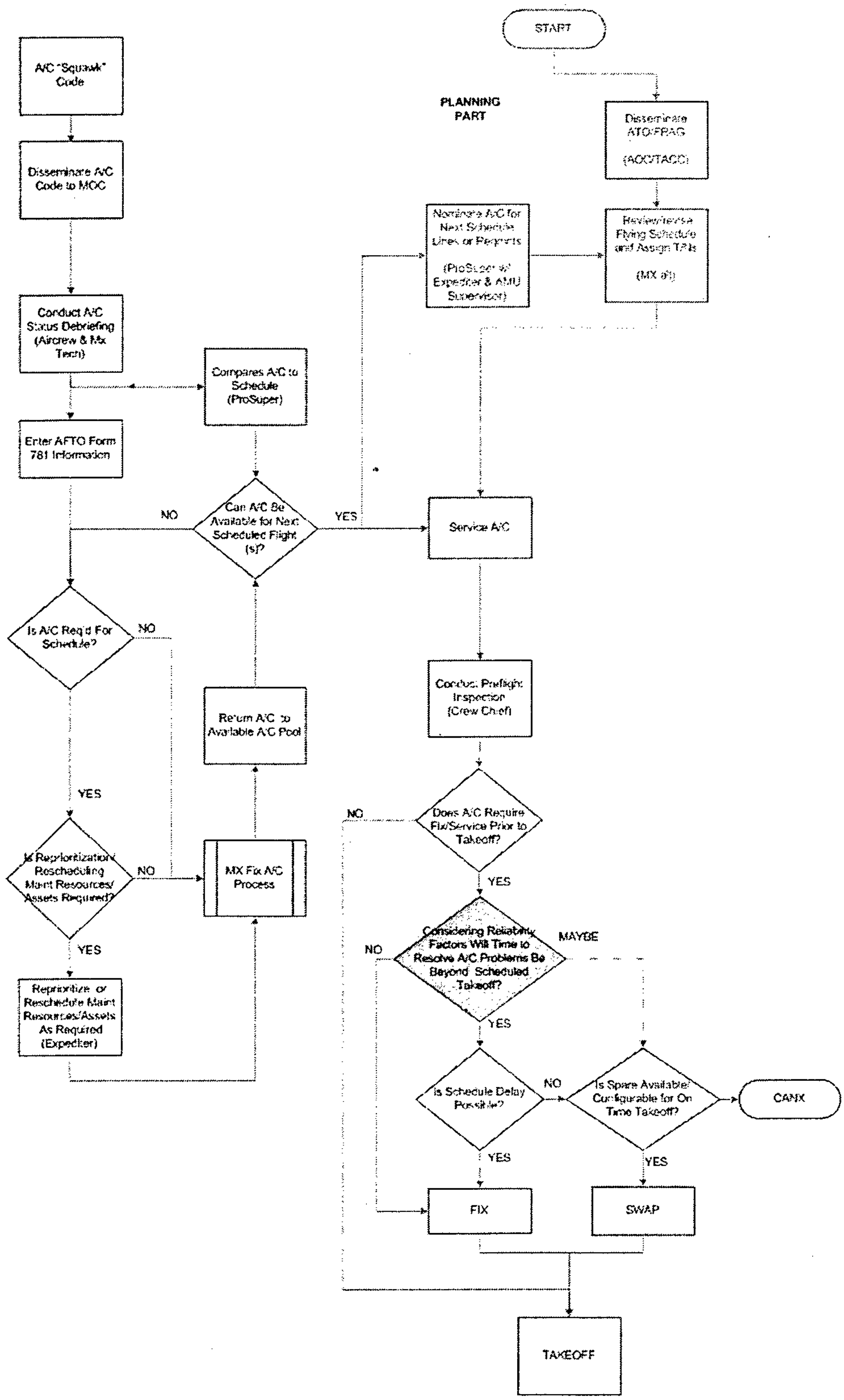


FIGURE 4: FLIGHTLINE MAINTENANCE PROCESS

The Expeditor assigned to the aircraft will record the squawked status on their fleet status board and pass the status on to the MOC and the ProSuper. This step is sometimes reversed where the pilot squawks over the aircraft radio and provides the data to his operational unit who passes it to the MOC who then passes it on to the ProSuper and Expeditor. Once the aircraft lands the aircrew reports to the debriefing facility (AKA debrief) to discuss the aircraft maintenance issues or "write-ups" with the appropriate maintenance technician. This process helps to further define the aircrew's "write-up" which is only a short paragraph logged into the Aircraft Air Force Technical Order (AFTO) Form 781 binder (AKA: The Forms). Typically the problem is much more complex than the available space in the 13 lines of the AFTO Form 781a Discrepancy block. Occasionally the problem is assigned to a different system and maintenance specialty from the original squawk based on the debrief information. After debrief, the Aircraft Forms are passed to the Expeditor who transfers the entries into one line summaries on the fleet status board and returns the forms to the proper aircraft. The Expeditor then decides the priority of which problem needs to be worked by which specialist on which aircraft. Often there is no need to consider priority as there are fewer problems to work than specialists in the relevant specialty. In the event that multiple problems exist for a given specialty, a decision will have to be made based on overall priorities established by the ProSuper and/or Aircraft Maintenance Unit (AMU) supervision.

As soon as the squawks are confirmed in debrief the ProSuper compares aircraft status changes to the schedule. The ProSuper works in concert with the Expeditor and AMU supervision to nominate aircraft against the schedule "lines" (requirements). Both the remainder of the current day's flying schedule (in execution) and the requirements for the following day have to be considered. At the same time, the Expeditor is trying to determine if the broken aircraft will be available for next scheduled flight(s).

On the morning of the flying schedule execution Crew Chiefs ready the aircraft, oversee servicing, and perform the required "preflight" inspection. As issues and errors are discovered, the Expeditor ensures the appropriate maintenance technicians are dispatched to make corrections. Soon maintenance actions take on the frenzied "red ball" status. According to Air Force Instruction (AFI) 21-101 [1], "…"Red Ball" maintenance

normally occurs two hours prior to launch and until aircrew have released the aircraft back to maintenance." It is not unusual to have a maintenance technician working a red ball over the lap of a pilot just minutes before (or after) scheduled launch time.

If no problems are encountered the engines are started, taxi and takeoff follow according to schedule. However if a problem is encountered the ProSuper and Expeditor must decide if there is enough time to resolve the problem before scheduled takeoff. If the resolution or "fix" time is expected to be within the schedule window, then the aircraft goes to Fix. If not, the ProSuper, Expeditor and operations personnel make considerations to move the aircrew to the spare aircraft (if one exists). If no spare aircraft exists and the mission is cancelled, many times a second aircraft will "sympathy abort" because doctrine does not permit one fighter to proceed alone. Depending on the number of aircraft launching, the assigned mission and the remaining pilot's qualifications, the second aircraft may join with other aircraft to complete its mission.

3.2.2 Cognitive Task Analysis Representations

The goal of developing a cognitive model is to understand the Expeditor's information needs, decisions, goals and strategies for conducting their job. The cognitive model provides a foundation for SSLC2 development. The data collected for the development of the cognitive model includes the original interviews conducted at the beginning of Spiral One, interviews with the SMEs from AFRL, and a concept mapping with one SME. These data are presented using a hierarchical task analysis, a concept map, and OFM-COG models [9]. The results of each are presented in the sections below and diagrams are documented in Section 2.3 of Appendix B: Data Collection. The information from this analysis is used to identify opportunities for providing the right type of support in SSLC2.

3.2.2.1 Concept Map

Researchers met with a SME to elicit knowledge about the Expeditor's task using a concept map approach. A concept map represents elicited knowledge as a series of nodes (concepts) connected by lines representing the relationships between the concepts. The concept map is built interactively as the expert describes their tasks and their understanding of the domain. This technique helps to organize the domain concepts and

to transfer the information from the expert to the design team [4, 10, and 15]. The concept map is presented in Figure 5. Blocks outlined in Red indicate tasks carried out by the Specialist, not the Expeditor.

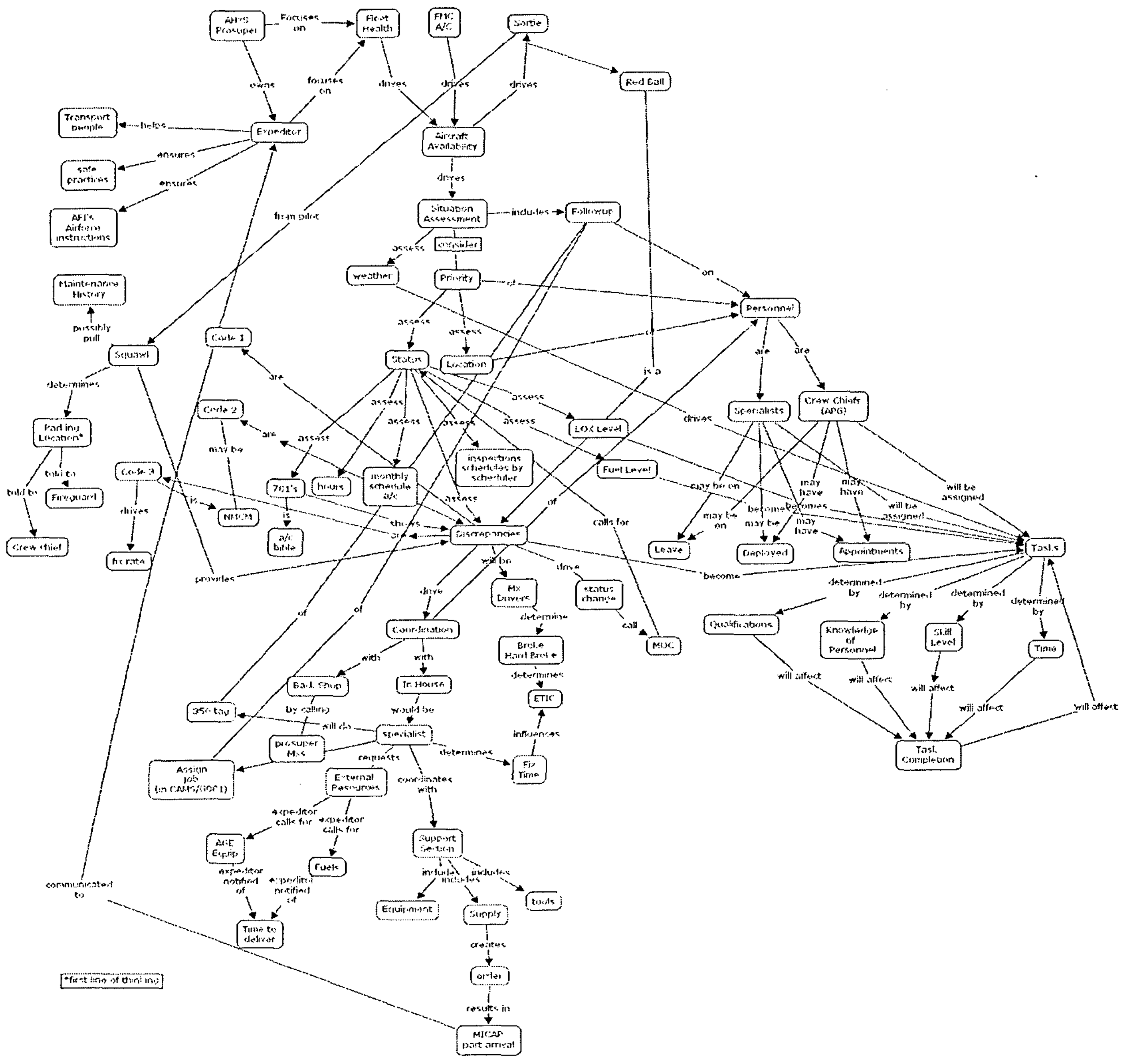


FIGURE 5: EXPEDITOR CONCEPT MAP

3.2.2.2 Hierarchical Task Analysis

The primary role of the Expeditor is to monitor flightline maintenance and to expedite or assist maintenance so flights can meet their sorties. They facilitate the assignment and movement of resources (equipment and people) to meet the maintenance needs. Table 2

provides a description of major tasks. Spiral One concentrated on Tasks 1- 6, which are presented in the hierarchical task diagram contained in Section 2.3.1 of Appendix B. These diagrams illustrate the tasks at a high level.

TABLE 2: EXPEDITOR/PROSUPER TASK LIST

Task Name	Description
1. Prepare for Status meeting (start of day)	Reviews information related to the current status of the flightline, aircraft, personnel, schedules
2. Monitor flightline maintenance	Monitors the flightline, receives status updates, requests needed resources
3. Monitor aircraft landing	Monitors aircraft landing, determines squawk code and possible problems
4. Launch aircraft	Monitor and document aircraft launch from air crew show to take off
5. Assess aircraft status	Assess aircraft state and determine aircraft status (FMC, PMC, NMC)
6. Evaluate fleet health	Evaluate overall health of aircraft, review maintenance metrics

3.2.2.3 Operator Function Model and Cognitive Information (OFM-COG)

An OFM-COG was created to present the Expeditor's Cognitive Model [9]. For the OFM 4 sub-functions of the Monitor Flightline Maintenance were identified: Monitor aircraft launch, Monitor aircraft landing, Assess aircraft status, and Evaluate fleet health. Information related to evaluating fleet health was not collected. Section 2.3.2 of Appendix B contains the four sub-functions using the OFM technique and the OFM-COG analysis of each sub-function. The definitions for the Task agents specified in the tables can also be found in Section 2.3.2 in Appendix B.

3.2.2.4 Summary of Expeditor Tasks

The primary role of the Expeditor is to monitor flightline maintenance and to expedite or facilitate maintenance so flights can meet their sorties. Personnel who are selected to be Expeditors have typically worked on the flightline as Crew Chiefs and/or Specialists. They have several years if not many years of experience with the flightline and specific maintenance issues. An Expeditor is required to be out on the flightline at all times. Their office is in their vehicle, which they use to move equipment and people, with little time available for data input. They use clip boards with paper to store and retrieve information and rely on radios for communication and to help them maintain situation awareness. The environment can be described as high stress, especially when deployed where they

often work twelve hour shifts. The Expeditor is interrupt driven, and must juggle many tasks at one time.

The Expeditor's primary focus is to ensure sorties are met. They review daily, weekly and monthly schedules and use paper schedules on which they make notes. The schedules and reports used vary among maintenance units and bases and are usually created in a spreadsheet file and updated at the beginning and end of a shift.

At the beginning of a shift the Expeditor meets with the ProSuper and personnel from the previous shift (Expeditors, ProSuper, Scheduler) where he is updated on all aircraft status and maintenance phases. They are also updated on personnel information. Any issues or problems are described during the meeting. This meeting is essential to provide the Expeditor with current situation assessment. The Expeditor reports to the ProSuper and updates the ProSuper throughout the day. In some cases the ProSuper is also the Expeditor. Decisions at start of shift may include what personnel to assign to various tasks based on who is available and skill sets. They may also make recommendations to the ProSuper to change aircraft tails to sorties based on updated aircraft maintenance stage, sortie schedule, or supply availability information.

Throughout the shift Expeditors are assessing aircraft status and maintenance stages. They monitor all aircraft taking off and landing. In addition to the primary tasks listed in Table 2, the Expeditor is also responsible for ensuring safe practices and AFIs are being followed.

The Expeditor makes a decision to fix or swap an aircraft in order to meet a sortie and provides their fix/swap recommendation to the ProSuper or maintenance supervisor, who has final say. They may also recommend to delay or cancel the sortie. A swap aircraft may be a spare, or another aircraft on the flying schedule. They may also make decisions to pull human or equipment resources from one aircraft to another in order to meet the schedule. They focus on meeting the schedule and trying to limit interruptions to other on-going aircraft maintenance tasks. Expeditors often pull resources they can see within their immediate area. Decisions are made quickly, relying on previous experience. They rely on knowing what stages aircraft are in and where personnel are assigned. They often call for resources throughout the day.

3.3 STORYBOARD DEVELOPMENT

Leveraging information captured during data collection and knowledge representation stages, a series of concepts and storyboards were created and used as input into the Graphical User Interface (GUI) design as well as the software use cases for development of the simulation test system (see section 3.4 for discussion of software).

The cognitive task analysis indicates a basic workflow that can be described as follows:

1. Pre-problem flightline monitoring;
2. Assessment of a specific problem occurring on the flightline;
3. Weighing trade-offs with regard to fixing or swapping the aircraft; and
4. Executing the decision and monitoring progress toward that resolution;

Using this task structure, several scenarios were created to follow this flightline decision making process.

To develop the GUI the information needed by the Expeditor and/or ProSuper was determined and a framework for the work process was identified. The framework established screen locations for the information to be displayed. The framework was modified from a framework used during the LOCIS project. Figure 6 shows the basic framework. Using this framework, all screen designs for the SSLC2 simulation test system were created. For any given screen, the information elements were mapped to their appropriate areas using the framework. Figures 7 and 8 illustrate two of the GUI screen designs. The left side of the screen shows the workflow process steps (e.g. assign assessor, perform assessment, and verify resources). The central portion of the screen provides schedule and geographic views. These views can be changed from an overview of the entire flightline, to a problem view focusing on one aircraft.

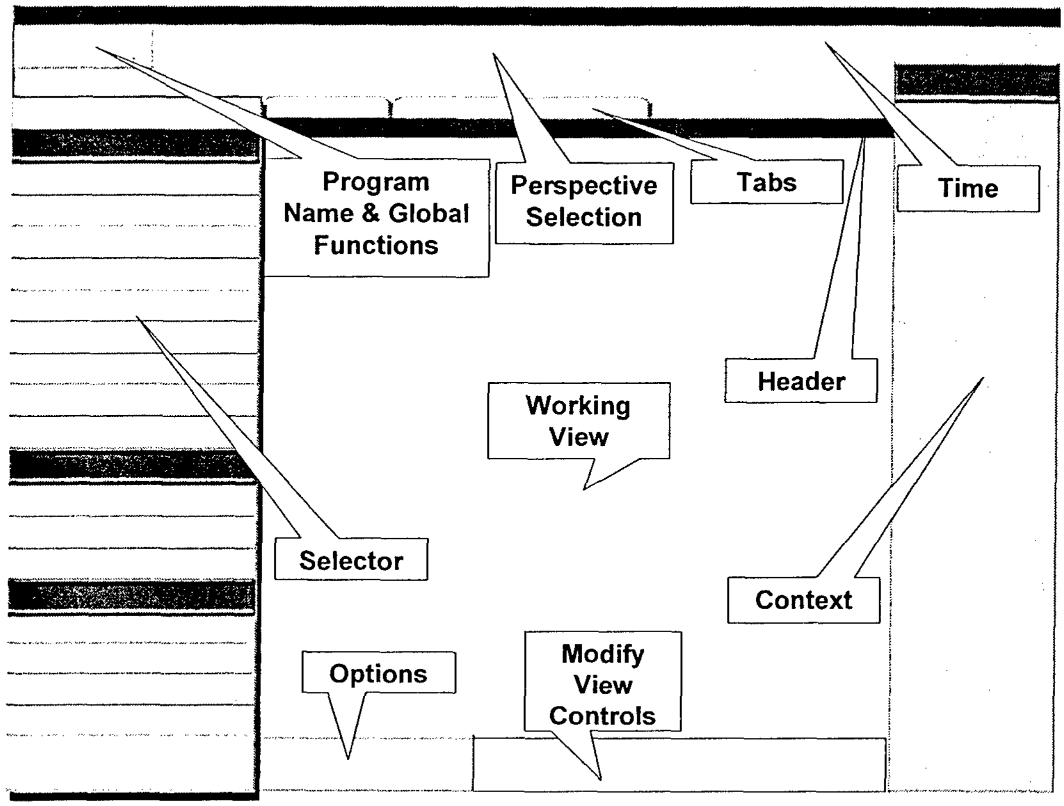


FIGURE 6: SSLC2 SCREEN DESIGN

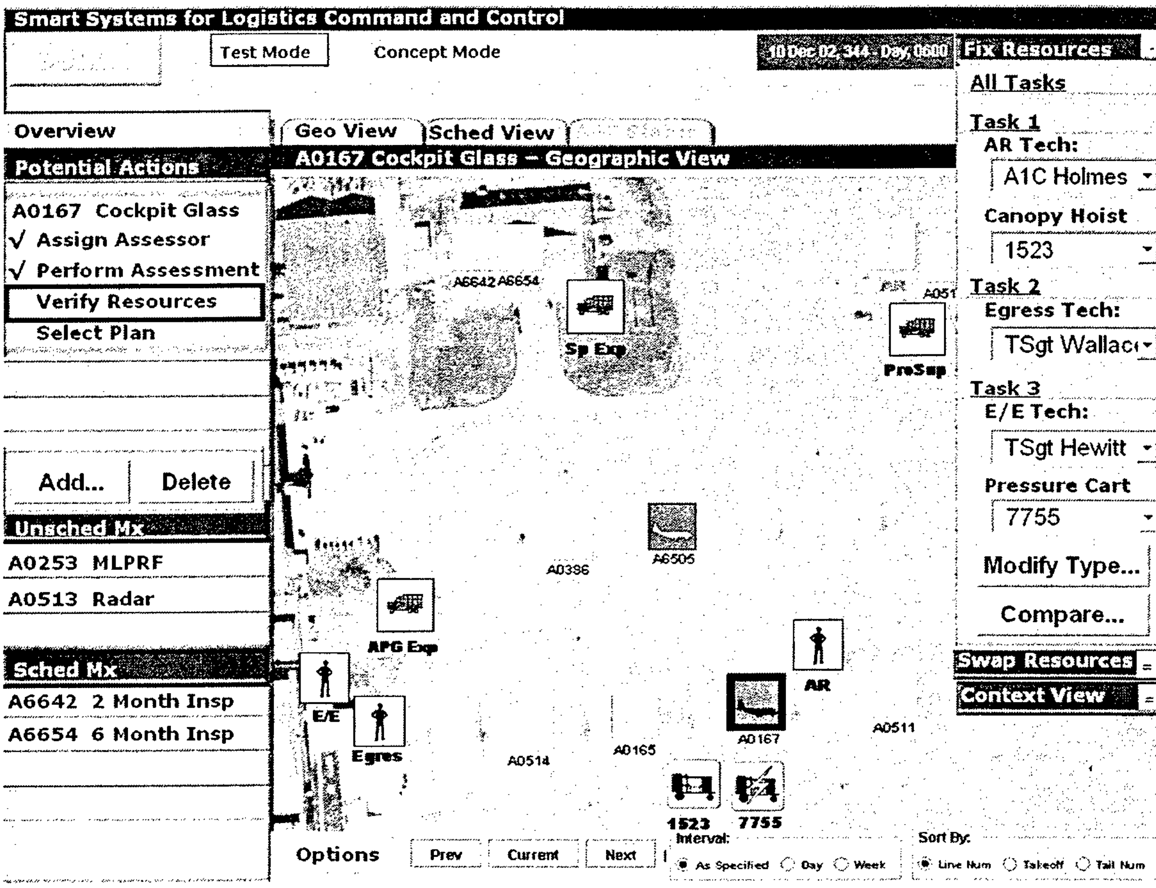


FIGURE 7: SSLC2 GEOGRAPHIC VIEW

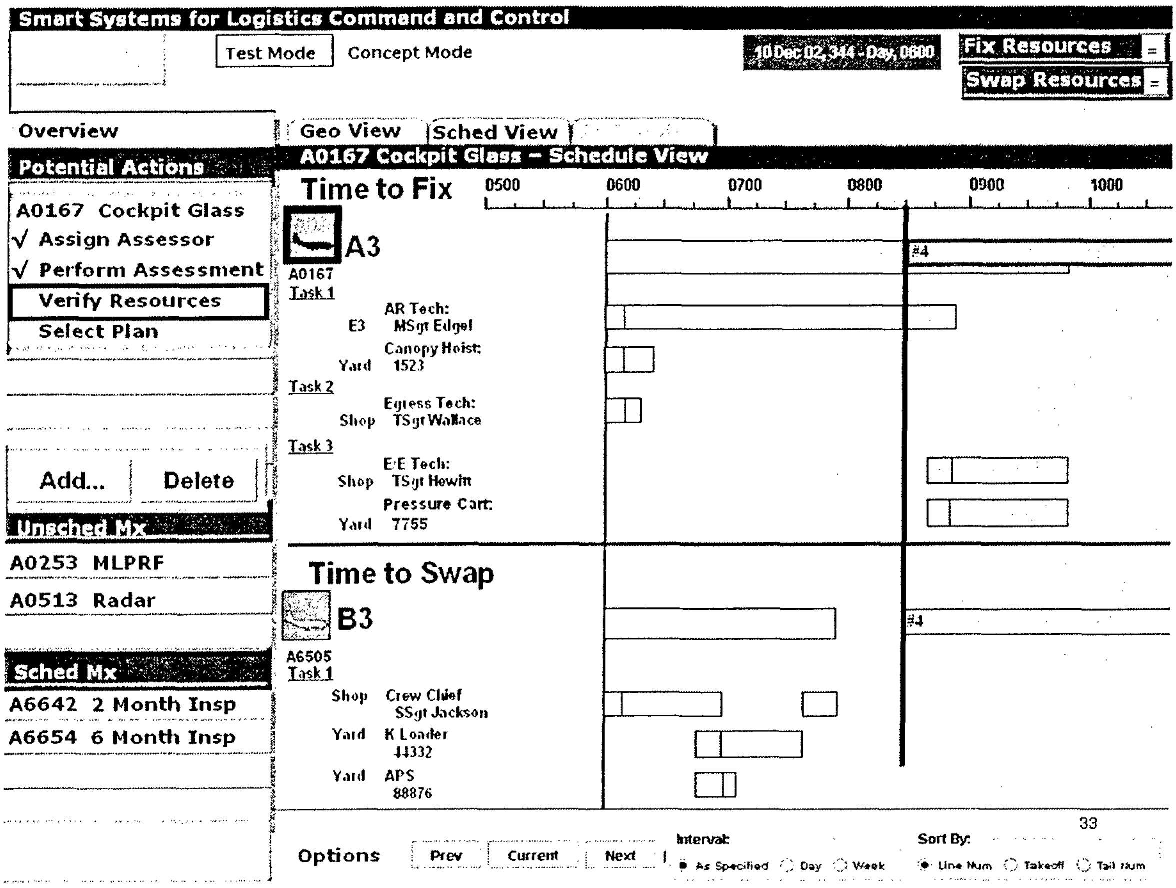


FIGURE 8: SSLC2 SCHEDULE VIEW

3.4 SIMULATION TEST SYSTEM DEVELOPMENT

The purpose of the simulation test system was to provide the ability to test as well as demonstrate SSLC2 concepts. This section briefly details the overall software architecture followed by more detailed information including software reuse from the LOCIS program, use case specifications, requirements and model traceability, activity and/or design model, algorithms and business logic, and database.

3.4.1 Software Architecture

SSLC2 is a three-tier thin client web application. The client tier is a thin client web application that incorporates the GUI. The only commercial software requirement for the client machine is Microsoft Internet Explorer version 5 or greater and a Java Virtual Machine version 1.4 or greater. All the GUI objects are downloaded to the client the first time the computer accesses SSLC2. Subsequent client requests result in download of data only. This design reduces the bandwidth requirements and provides a responsive system.

The middle tier, the business logic of SSLC2, is comprised of servlets currently developed and hosted on WebLogic version 7.0; however, SSLC2 could be rehosted to run on any web server that supports Java server pages, servlets and applets.

Communication to the 3rd tier, the database, is via industry standard Java Database Connectivity (JDBC) protocol. The database used is Oracle 9.0.2 and can be hosted on the same server as the middle tier web server or on a separate server.

The only other software interface created in Spiral One was an interface to the WhereNet server which provides the simulated resource location data. The WhereNet server, a separate server from the SSLC2 server, supports communications via HyperText Transport Protocol (HTTP). A server side process was created that subscribes to events on the separate WhereNet server via HTTP, in order to receive location information. This information is retrieved by SSLC2 by pinging the WhereNet Application Programming Interface (API) at a timed interval and then inserted into the SSLC2 database via JDBC.

3.4.1.1 LOCIS Reuse

Capitalizing on the previous AFRL/HEAL project, LOCIS, SSLC2 was able to produce a thin client web application prototype for the Spiral One Scientific Study. This section discusses the major software components of LOCIS reused in SSLC2.

The major LOCIS reuse centered on the software framework. These elements included: database tables, servlets, data objects, communications object used to transmit data to and from the server, the main applet window, and navigation elements of the main element. The framework elements are those objects and tables used to deliver views. In order to accommodate SSLC2 design elements, the GRACAR team changed some framework elements to incorporate Roles. Roles, briefly discussed in section 3.4.1.6, required framework redesign to accommodate the Selector Area on the left side of the applet window.

The original LOCIS geographic view was reused to provide the SSLC2 Geographic view. Changes to this element involved expanding the aircraft icon object to support other types of equipment. The capability for icons to "stack" was an enhancement to the

original LOCIS geographic view. Elements of the geographic view were also reused in the resource select screen.

Spiral One did not include the exact LOCIS flying and maintenance schedules; however elements of the LOCIS schedule view were used to create the SSLC2 problem schedule view.

A fourth element of LOCIS reuse is the development environment. The build environment included batch files and Apache Ant build scripts that compiled the source files and created a deployment directory containing the entire web application. This allowed for a simple "drag-and-drop" development method to deploy updates to the SSLC2 application.

Generally, the decision to reuse LOCIS elements or not was based on SSLC2 functionality requirements. The development approach was to strip LOCIS down to the basic framework and then reintroduce elements meeting SSLC2 needs.

3.4.1.2 Use Case Specifications

A use case describes a sequence of actions a system performs yielding an observable result to a particular actor. A series of use cases were created describing how SSLC2 interacts with the Expeditor. The use cases describe each screen giving a basic description, flow of events, alternative flows, special requirements, preconditions, post conditions and any additional actors. The use cases illustrate exactly how SSLC2 will respond to input.

3.4.1.3 Requirements and Model Traceability

Essential to documenting the SSLC2 requirements is the capability to trace from the source, such as a literature search documents, interviews, previous research efforts, through the Use Cases to the software components and test cases. An initial literature search of logistics command and control efforts and previous AFRL research efforts generated a list of requirements that were then validated and expanded during data collection utilizing the SME generated scenarios. The requirements were then grouped into display, schedule, parts, interface, reporting, resources, and problem requirements. Use Case specifications were developed from these requirements and linked to specific software components and then test cases.

3.4.1.4 Activity and/or Design Model

For Spiral One, SSLC2 begins when a problem is already identified, assessed and verified. Task steps for fixing or swapping the aircraft and times and types of resources are known and in the system. SSLC2 assigns resources based on proximity to the problem aircraft. Using SSLC2 the Expeditor monitors the flightline and is alerted when the problem is entered into the system. The Expeditor's first step is to Verify the Resources. SSLC2 displays the technical order tasks, times for each task, and resource times to site. The Expeditor reviews the resources assigned by SSLC2 for both the fix and the swap solutions. The Expeditor can override recommendations, select any additional resources or manipulate times based on experience.

The scenario concludes with the Expeditor selecting a course of action. His options are to fix or swap the aircraft or delay or cancel the sortie. If fix is selected, the SSLC2 concept is to automatically notify resource managers, technicians, and inform the ProSuper. If swap is selected, it is considered a recommendation that goes to the ProSuper for approval. The final option is to recommend delay or cancel. This also becomes a recommendation to the ProSuper who in turn negotiates a course of action with Operations. In SSLC2, the problem information as well as the potential solutions would be presented to the ProSuper to facilitate the negotiations.

3.4.1.5 Algorithms and Business Logic

The SSLC2 simulation uses three algorithms to determine 1) AGE availability, 2) which aircraft to swap, and 3) resource transit times. The logic for these algorithms is described below.

1. AGE Availability – The specific location of resources was specified in WhereNet. In this system it is possible to define zone labels within the RTLS coverage area. The zone information is encoded within the RFID tag and sent in the message to SSLC2. Zones were defined for the entire flightline, each parking location, AGE yard, ready lines, etc. In order for SSLC2 to consider a piece of AGE as being available and therefore recommend it's use, it had to be FMC and

in any available zone. AGE in any other location was available to be manually selected.

2. Candidate Swap Aircraft – SSLC2 not only recommends resources to meet a fix requirement but also recommends resources to meet a tail swap requirement. One of the resources needed is a candidate tail for the swap. SSLC2 used the following logic:
   - If there is a aircraft designated as a spare on the flying schedule then that is the candidate swap;
   - If there is not a spare designated, the candidate tail is the last flyer on that day; or
   - If no other flyers are available, then select an FMC aircraft.
3. Resource transit times – A rudimentary algorithm was included to compute resource transit times. This algorithm is a straight line path-of-travel along with discrete radii regions (e.g. a truck which is between 2 km and 3 km away will take 8 minutes to travel that distance). Travel speeds used were: Trucks: 15 mph, AGE: 5 mph, and Personnel: 2 mph.

3.4.1.6 Database

The majority of the database design was inherited as a bi-product of reuse of LOCIS. However, there were some significant changes from LOCIS in order to accommodate SSLC2. Changes included design elements such as Roles, storing AGE/personnel information, and aircraft problems that result in a fix or swap. The aircraft problem requirement generated the need to be able to associate tasks, resources, and times to both the fix and swap options.

The roles concept equates to a specific set of software capabilities that are available to different types of users. The capabilities relate to the types of views the user is able to access.

The original LOCIS database was designed to handle aircraft data elements. SSLC2 expanded on this concept by manipulating tables to add equipment and personnel data elements.

The SSLC2 database also contains information related to aircraft problems. Database elements include:

- Tasks necessary to fix the broken aircraft;
- Tasks necessary to swap from the broken aircraft to a spare for the sortie;
- Time necessary to accomplish each task;
- Resource types necessary to accomplish each task; and
- Specific resources assigned to the tasks.

4 Scientific Study Approach

4.1 OBJECTIVES

To evaluate enhanced data streams provided by RFID/RTLS technology a Scientific Study was undertaken. The study was designed to compare three conditions. The SSLC2 approach which integrates RFID/RTLS technology with flightline information for improved decision making was compared to an off-the-shelf technology that provides RFID tags. The off-the-shelf technology called WhereNet provides location of resources but does not integrate the information with the Expeditors work and decision process. In addition to these two conditions, a Baseline condition was included as a control condition. This allows for comparison of the SSLC2 approach to current practice and also enables validation of the cognitive model.

The Scientific Study objectives were:

1) To validate the cognitive model developed from data collection interviews through verbal protocol (source) techniques and to determine what information is most useful to help Expeditors make flightline decisions.

2) To evaluate user performance and opinions on enhanced data streams.

The Scientific Study focused on the fix or swap decision construct identified in the data collection and cognitive task analysis processes. The verbal protocol technique was used to collect data related to the types of information and processes the Expeditors use to make the fix/swap decision. During the study, participants were asked to provide

estimates of time to site for resources. This estimate was used as one dependent variable. The hypothesis was that participants would provide less variable time to site estimates when using the SSLC2 integrated information system approach than when using the WhereNet off-the-shelf RFID/RTLS technology system, or current practice (Baseline condition).

Participants were also asked to provide their opinions of the three conditions. The hypothesis was that participants would prefer the SSLC2 approach compared to the WhereNet off-the-shelf RFID/RTLS technology system. Because participants are so familiar with current practice and often resistant to change, it was hypothesized that there would be no difference in preferences between the SSLC2 approach and the Baseline current practice approach.

4.2 DESIGN

The experimental design was a within-subject full factorial design. Each participant received three conditions: Baseline, WhereNet and SSLC2. The Baseline condition was similar to how Expeditors currently carryout their task. They were provided paper references and used a radio for all communications. The WhereNet condition included all the same paper references provided in the Baseline condition as well as the WhereNet software which provided information regarding the location of flightline resources (equipment and personnel). Again, all communication was via radio. The SSLC2 condition was represented through the simulation system and included decision support as well as monitoring, location, and availability of resources. The radio was available for communication, but mostly used for receipt of messages.

4.3 PARTICIPANTS

Eighteen people volunteered to participate in the study. Two criteria were established for participation in the study. First, the participant had to have worked as an Expeditor or ProSuper within the past five years. Second, they must have performed these duties for at least six months. Anyone responding to the study was permitted to participate and provide feedback on the conditions presented; however, data were only analyzed

statistically for those participants who met these two criteria. Sixteen of the eighteen participants met these two criteria.

Participants were from the 445th Airlift Wing AFRES at Wright-Patterson AFB, OH; 179th Airlift Wing at Mansfield ANG, OH; 180th Fighter Wing at Toledo ANG, OH; and 122nd Fighter Wing at Ft. Wayne ANG, IN. Nine participants dealt with airlift aircraft, and nine participants handled primarily fighter aircraft. Of the fighter participants, one was not able to complete all three conditions, one was not able to complete all the questionnaires, and one did not meet the criteria established. The data for fifteen participants were analyzed for statistical significance. Nine were experienced with airlift aircraft while six were experienced with fighters.

4.4 APPARATUS

Three computers running Windows XP were used for the study. A desktop computer ran the SSLC2 server and the Oracle server with the database. This machine was a Pentium 4 with a 3 GHz processor and 512 megabytes of random access memory (RAM). A second Pentium 4 desktop computer with a 2.4 GHz processor and 1 gigabytes of RAM ran the WhereNet server. The third computer was a laptop that the participant used during the study to interface with the servers. The laptop was a Pentium 4 with a 1.4 GHz processor and 512 megabytes of RAM. Internet Explorer was the browser used to communicate with the servers. The computers were linked together using two hubs.

Two Motorola Radius P1225 Portable Two Way Radios were used for communication. The radios operated in the 450-470MHz Ultra High Frequency (UHF) band, and had two channels with a power output of four watts. The participant used the radio to contact various maintenance personnel. Maintenance personnel were role played by one of the researchers. At one location, the base communications function requested that their radios be used to alleviate frequency coordination problems. No data are available on the types of radio used in that location.

4.5 RESEARCH TEAM

The study teams consisted of five researchers with different roles. The Lead Experimenter was responsible for interacting with the participant. This person

administered all forms, asked all question probes, and generally answered participant questions. The Data Collector sat in the room with the Lead Experimenter and the participant and was responsible for capturing all discussions occurring during the session. This included video, audio, and typewritten information. The SME was responsible for making the scenario come alive. To simulate actual flightline conditions, radios were used to communicate information occurring on the flightline. These radio communications occurred between the SME and the participant. Events in the scenario were scripted ahead of time. The fourth researcher role was System Administrator. This person set up the equipment and was responsible for advancing and playing the software scripts associated with each scenario. These software scripts were synchronized with the SME verbal scripts to enhance the realism of the events from the simulated flightline. For example, the SME might call over the radio and tell the participant a resource was on its way; simultaneously the technology would simulate this movement. The final researcher was the AFRL/HEAL Research Coordinator and was responsible for officially setting up the interviews and interfacing with base personnel. This person monitored all interviews from a functional perspective and ensured the experiments complied with all Air Force and base requirements. The SME, System Administrator, and Research Coordinator were located in a room adjacent to the room with the participant, the Lead Experimenter, and the Data Collector.

4.6 STIMULI AND MATERIALS

4.6.1 Experiment Stimuli

The experiment stimuli consisted of an overall scenario depicting the deployed environment, base conditions, and aircraft missions. A base map was also provided depicting the flightline with parking locations, aircraft maintenance units, ready line and other relevant base locations.

4.6.2 Baseline Stimuli

Baseline stimuli consisted of paper information sheets which included a personnel roster, equipment list, and a daily status sheet that included each aircraft with their status, daily flight schedule, and maintenance schedule.

4.6.3 WhereNet Stimuli

WhereNet stimuli consisted of the same paper information sheets used in the Baseline condition as well as the WhereNet software. Figures 9 and 10 illustrate the two primary visual screens used in WhereNet. One screen is a report view (Figure 9) which allows the user to view resources in a list format and to filter the information. The second screen (Figure 10) is a map view which allows the user to see the geographic location of the resources on a map.

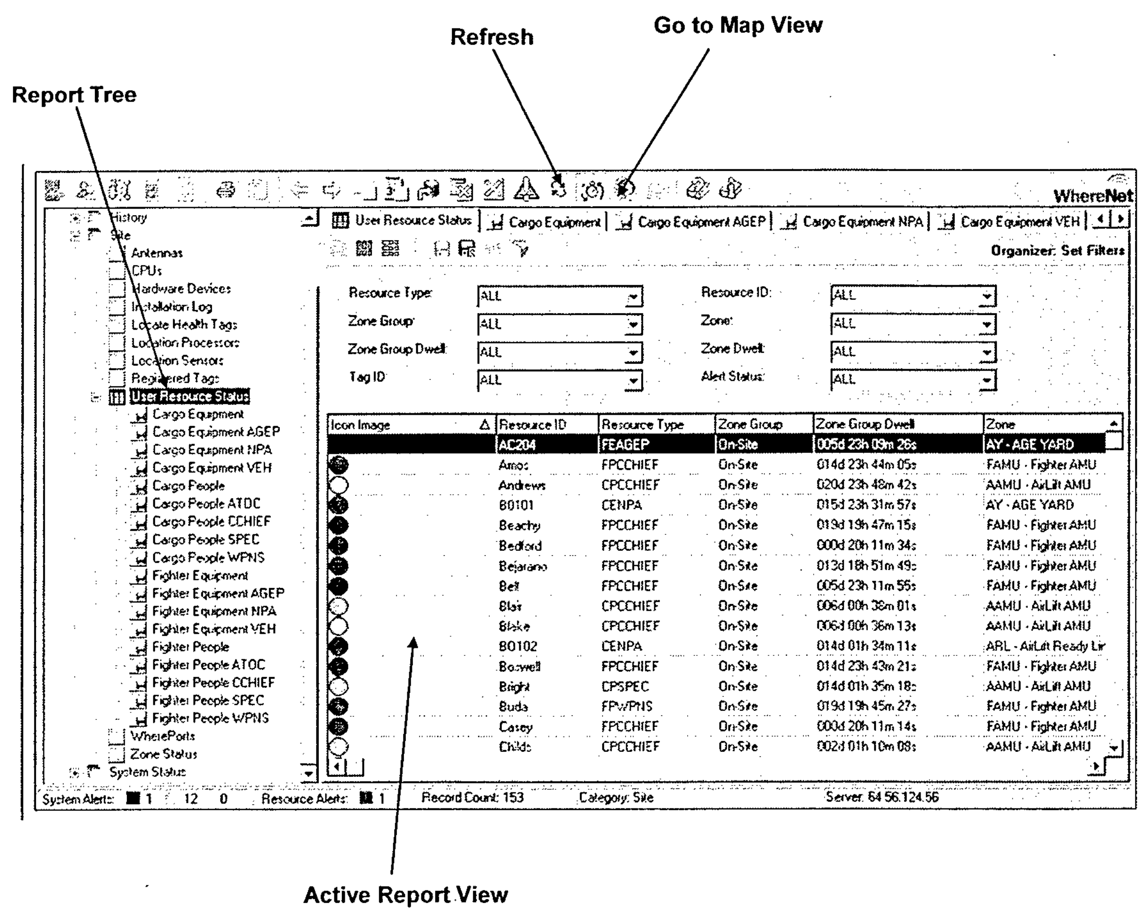


FIGURE 9: WHERENET REPORT VIEW

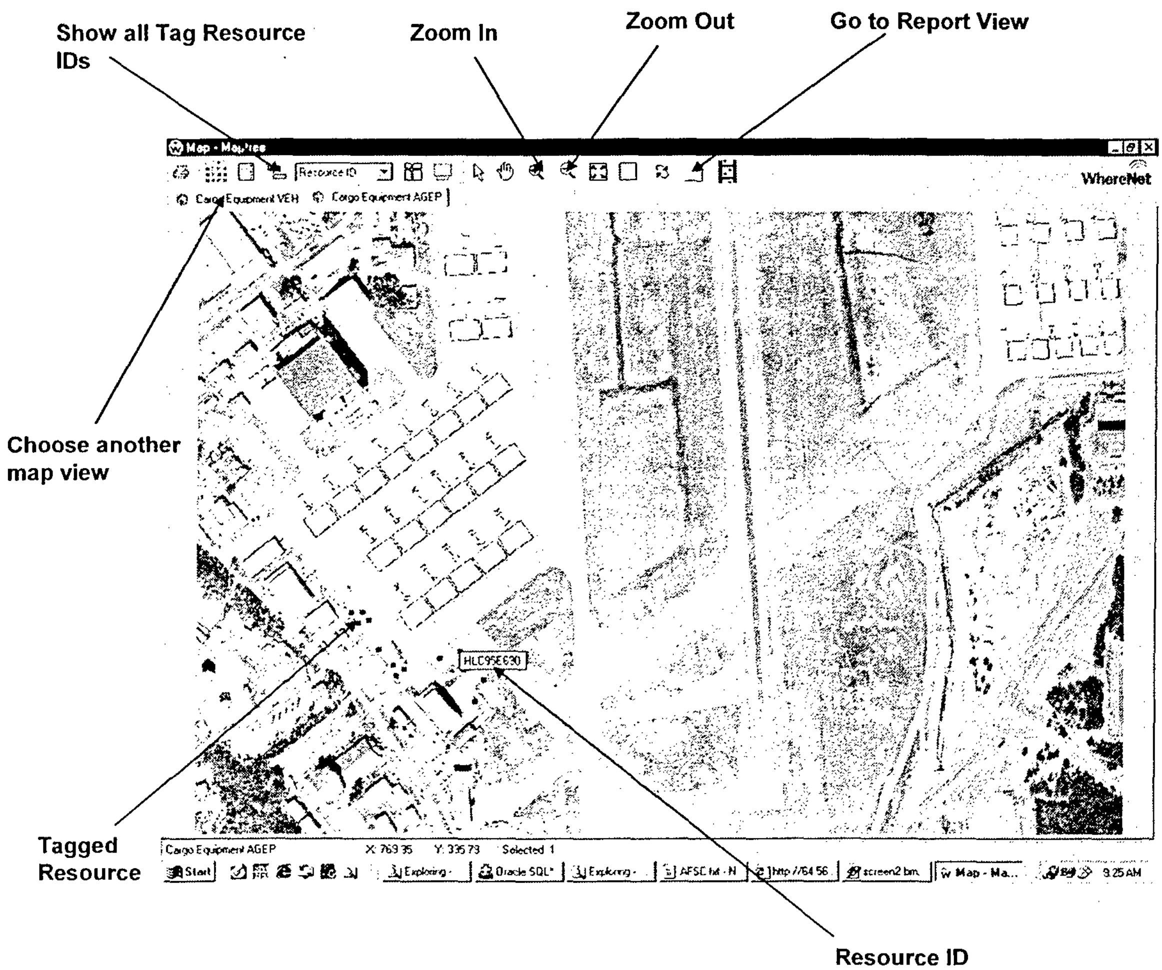


FIGURE 10: WHERENET MAP VIEW

4.6.4 SSLC2 Stimuli

SSLC2 consisted of the simulation test system. During this condition participants were not given any paper materials. The system provided aircraft status and location, aircraft maintenance schedules, daily flying schedules, personnel and equipment resources and their locations, tasks necessary to fix the broken aircraft, tasks necessary to swap an aircraft, time to complete fix tasks, time to get resources to the fix site, resource types necessary to complete tasks, specific resources assigned to tasks, and a recommendation to fix or swap an aircraft. Figure 11 illustrates the geographic view of SSLC2. Figure 12 illustrates the schedule view.

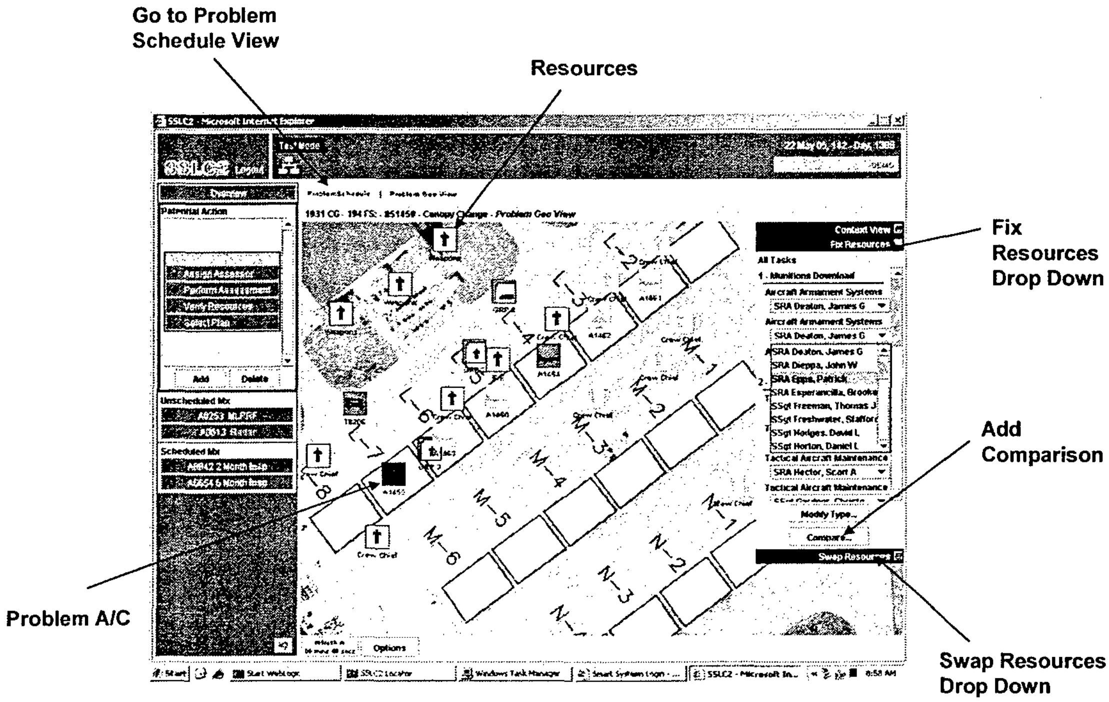


FIGURE 11: SSLC2 PROBLEM SPECIFIC GEOGRAPHIC VIEW

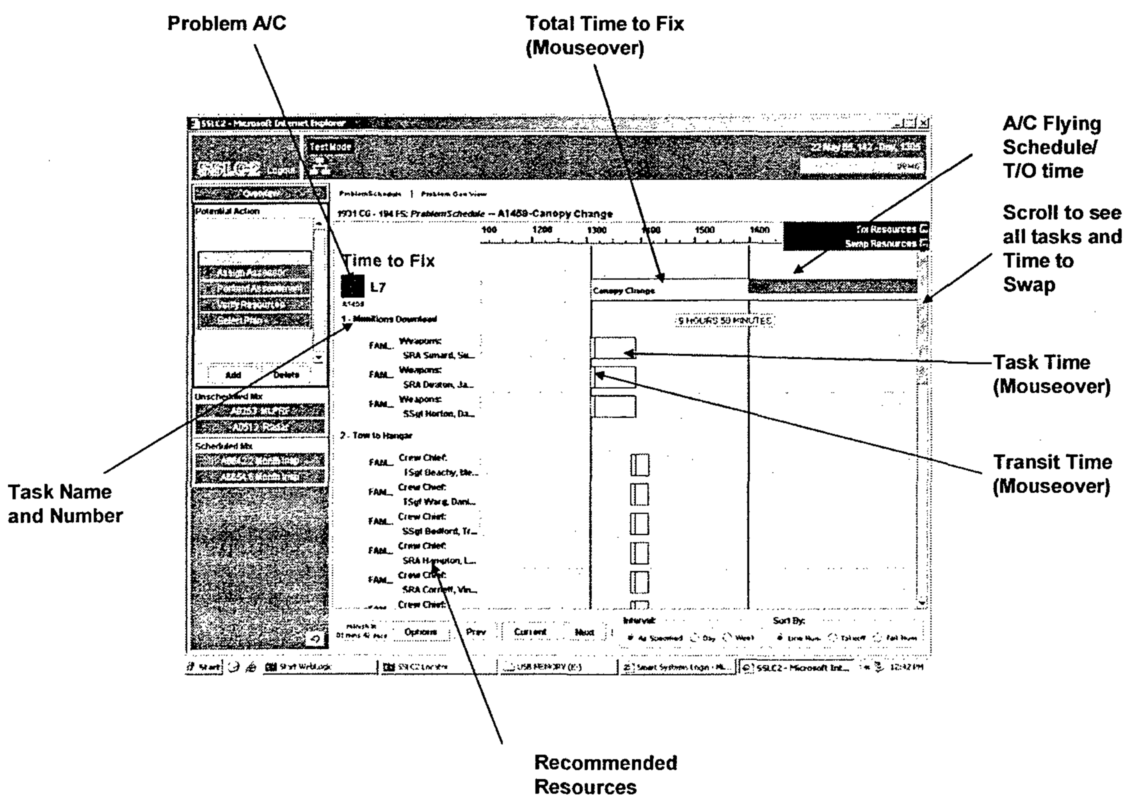


FIGURE 12: SSLC2 PROBLEM SPECIFIC SCHEDULE VIEW

4.6.5 Scenarios

The study was conducted by creating scenarios in which an aircraft on the flight schedule has a specific maintenance problem. The participant acting as Expeditor must analyze the problem and determine whether to fix or swap the aircraft. The scenarios were designed to have three triggers. Time would advance between each trigger. At the beginning of the scenario, the participant would monitor the flightline (review the current state of the aircraft and flightline). The first trigger was an aircraft maintenance problem. The problem has already been assessed and verified by a specialist. Once the information is received the participant works the problem, decides to fix or swap, provides estimates to time, and begins the fix. After completing this trigger, a second and third trigger occurred in which a resource had to be replaced. One trigger was a personnel resource and one was an equipment resource. The participant would work through replacing the resource.

Four scenarios were created, each with a different aircraft problem. Scenarios were adapted for either fighter or airlift participants. The scenarios included the following: 1) Gland Nut Change, 2) Cockpit Glass Change (airlift version) and Canopy Glass Change (fighter version), 3) Fuel Leak and 4) Prop Change (airlift version) and Engine Compressor Stall (fighter version). Three of the scenarios were used for the three study conditions while the fourth, the Prop Change/Engine Compressor Stall scenario, was used for training. All scenarios are presented in Appendix C.

4.6.6 Questionnaires and Surveys

Participants were given questionnaires to complete throughout the evaluation process. They were given a pre-test questionnaire, a post-condition questionnaire after completing each of the three experimental conditions, and a three-part post-test questionnaire at the end of the study.

The pre-test questionnaire requested information such as the participant's years of experience on the aircraft, their experience in using computing systems, and two questions related to the criteria for acceptance (i.e., Expeditor or ProSuper experience within the past five years and experience for a minimum of six months).

The post-condition questionnaire consisted of fifteen statements using a seven-point rating scale format where a rating of 1 indicated "strongly disagree" and 7 indicated "strongly agree" with the statement. Three of the questions related specifically to comparing the value of the technologies in supporting human performance [15]. Three questions were targeted toward estimating the technologies ability to support situation awareness and decision-making.

Part 1 of the post-test questionnaire asked participants to rank order their preference for technologies along five separate dimensions. The first three rankings were aimed at the monitoring, locating, and identifying availability of resources. The fourth and fifth rankings looked specifically at tracking time associated with resources and making decisions about fixing or swapping the aircraft. Part 2 and 3 of the post-test questionnaire were aimed at collecting additional information relevant to further development of SSLC2 capabilities.

4.7 PROCEDURE

The study was conducted in a standard office or conference room at the various study locations. Each participant completed the entire study in one 3 ½ hour (approximate) session. After informal introductions, they were briefed about the purpose of the study and were given an informed consent form to sign followed by the pre-test questionnaire, study conditions, and post-test questionnaire. The study conditions were counter-balanced across eighteen participants. The three scenarios where then randomly assigned to the conditions without replacement. Across the eighteen participants each scenario was paired with each experimental condition a total of six times. Participants were then randomly assigned to conditions.

Each condition started with a training session. The training session consisted of two parts. The radio communication system was briefly explained, including the call signs. All participants were familiar with how to use the radio. For the SSLC2 and WhereNet conditions the participant was trained on how to use the software. After technology training the participant was given time to interact with the technology until they felt comfortable. The second part of training allowed the user to step through a sample scenario. During scenario training two triggers were used, the first aircraft problem

trigger and one resource trigger. During this part of training the participant used the technology provided, and interacted with the SME over the radio to work through the problem. They practiced the verbal protocol thinking aloud technique. After training, subjects were asked to rate their comfort with the technology on a scale of 1-7, with seven being the most comfortable and then participated in the study trial.

During the study the participant was encouraged to think aloud as they were making decisions. Additionally, the Lead Experimenter asked question probes at appropriate times to capture information such as comfort with the technology, strategies used for making decisions, and estimates of time associated with movement on the flightline. After each condition was complete, the participant filled out the post-condition questionnaire. This process was iterated for each of the three conditions. Once all three conditions were complete the participant was given the post-test questionnaire and thanked for their participation.

5 Results and Discussion

This section begins by analyzing and discussing specific results including presentation of participant demographics, analysis of participant ratings and rankings, statistical analysis of the dependent variables comfort ratings, time to fix, and time to site, and verbal protocol analysis. A summary of the results with respect to the study of objectives is presented, followed by a discussion of observations which summarizes feedback and suggestions.

5.1 PARTICIPANT DEMOGRAPHICS INFORMATION

Participants represented both the Fighter and Airlift domains. The nine Fighter participants had an average of 18.85 years experience while those working Airlift had an average of 18.78 years of experience. Four participants had experience working both Fighters and Airlift. Various maintenance supervisory roles were represented. Table 3 lists the flightline roles and frequency. Participants had on average 4.6 years of experience being an Expeditor. Two participants had experience as ProSupers but were not Expeditors. There was an average of 2.9 years of ProSuper experience. Three participants had no ProSuper experience.

TABLE 3: FIELD TEST SUBJECT ROLES

Role	Frequency
Aircraft Maintenance Superintendent	2
Aircraft Maintenance Supervisor	1
Aircraft Mechanic Supervisor	3
Avionics Tech	1
Avionics Tech/Expeditor	1
Deputy Maintenance Superintendent	1
Expeditor	3
Expeditor/Pro Super	1
Expeditor/Maintenance Superintendent	1
ProSuper	4

All but one participant said they use the computer daily. The exception used the computer more than once a week. All participants had been deployed overseas, with an average of 19.7 times.

5.2 RATINGS AND RANKINGS ANALYSIS

The post-condition questionnaires and post-test questionnaires were analyzed for fifteen of the eighteen participants who met the screening criteria and completed the entire study. The results for each type of questionnaire are described in the sections below followed by a brief summary.

This section concludes with two further analyses, a Post-Study Questionnaire Part 2 which addressed Decision Impacts, and a Post-Study Questionnaire Part 3 which addressed Data Elements.

Additional findings from rating and ranking analyses regarding Key Performance Parameters are located in Section 5.8 SSLC2 Program Key Performance Parameters. Findings related to these parameters include rating and ranking data for tracking time, assessing human performance, providing situation awareness, assisting with decision making using the three technologies.

5.2.1 Post-Condition Questionnaire Results

The post-condition questionnaire asked participants to rate their agreement with fifteen statements on scale from 1 to 7 (1 strongly disagree, 4 neutral, 7 strongly agree) (see Table 4). An overall analysis averaging ratings across all fifteen statements was conducted. Additionally, each individual statement was evaluated across the three

conditions. In all cases, an Analysis of Variance (ANOVA) with a criterion level of 0.05 was conducted with a Greenhouse-Geisser correction. (Note that Greenhouse-Geisser is a very conservative correction.) Paired comparisons were also conducted when effects were significant using Tukey's test. Table 4 shows the statistical results and mean ratings for each condition. Data for one participant was dropped due to missing data for several questions.

TABLE 4 : MEAN RATINGS WITH TUKEY GROUPINGS*

Statement (1 – Strongly Disagree, 7 – Strongly Agree): F values, p, and Condition Means SS= Smart Systems, WN = WhereNet, BL = Baseline, **Bold p** indicates significant findings at the .05 level	
1. There was enough information at all times to carry out my tasks and make decisions. F (1,13) = 1.28, p= .2783 SS=6.43 WN=5.86 BL=5.64	9. The technology improved my resource utilization because I know where all my resources were. F(1,13)=11.41, **p =.0049** SS=6.57 (A) WN=5.93 (A) BL=4.62 (B)
2. There was enough information to monitor the status of resources on the flightline. F(1,13)=7.68, **p =.0159** SS=6.78 (A) WN=6.07 (A, B) BL=5.21 (B)	10. The technologies provided were usable. F(1,13)=3.54, p =.0825 SS=6.50 WN=6.07 BL=5.72
3. I was able to determine where my equipment resources were. F(1,13)=6.21, **p =.0270** SS=6.64 (A) WN=6.57 (A) BL=5.00 (B)	11. I was provided with useful decision support. F(1,13)=2.05, p =.1758 SS=6.36 WN=6.21 BL=5.50
4. I was able to determine where my personnel resources were. F(1, 13)=9.39, **p =.0090** SS=6.14 (A) WN=6.64 (A) BL=4.57 (B)	12. Decision support as provided through this technology would positively impact flightline maintenance. F(1,13)= 2.71, p =.1236 SS=6.21 WN=6.21 BL=5.35
5. I was able to identify the availability of my equipment resources. F=(1,13)=6.44, **p =.0248** SS=6.43 (A) WN=6.28(A) BL=4.78 (B)	13. It was easy to notice when there were problems with aircraft. F(1,13)=3.15, p =.0993 SS=6.14 WN=4.71 BL=5.00
6. I was able to identify the availability of my personnel resources. F(1, 13)=4.39, p =.0561 SS=6.07 WN=6.07 BL=4.64	14. When problems occurred, it was easy to understand the status and location of resources needed to address the problem. F(1,13)=3.03, p =.1053 SS=6.57 WN=6.21 BL=5.57
7. I was able to determine what specific tasks needed to be accomplished. F(1,13)=1.028, p =.3291 SS=6.43 WN=6.07 BL=5.92	15. When problems occurred, I was able to predict whether I could meet the flying schedule. F(1,13)=5.06, **p = .0424** SS=6.00 (A) WN=5.64 (A, B) BL=4.71 (B)
8. I was able to track time associated with the movement of resources on the flightline. F(1,13)=5.78, **p = .0318** SS=6.36 (A) WN=5.29 (A, B) BL=4.79 (B)	Collapsing across all 15 statements combined: F(1,13) = 8.98, **p = .0103** SS=6.37 (A) WN=5.99 (A) BL=5.13 (B)

* Letters next to means indicate Tukey Groupings. Means with the same letter are not significantly different.

When collapsing across all 15 agreement statements ($F(1,13) = 8.98$, $p = .0103$), there was a statistically significant difference in ratings between Smart Systems and Baseline, and WhereNet and Baseline. Examining each statement separately (Table 4), 8 of the 15 statements showed no significant differences among conditions. Of the 7 statements that showed statistical significance, Smart Systems was rated higher than Baseline. Four of the 7 statements indicated WhereNet was rated higher than Baseline. Smart Systems was not rated higher than WhereNet for any of the 7 statements. See Figure 13 for mean rating scores collapsed across all fifteen rating statements.

Statements 13-15 all dealt with aspects related to situation awareness (noticing, understanding, and predicting) and were also collapsed and analyzed for overall situational awareness assessment ($F(1,13) = 4.96$, $p = .0442$). Results indicated that Smart Systems was rated significantly higher than Baseline. However, when looking at each of these questions individually we see that only one aspect reaches statistical significance - predicting. Statements related to noticing and understanding showed no difference among the ratings. We can not conclude, therefore, that situation awareness is improved for all aspects of Situational awareness.

Statements 10-12 dealt with human performance with the tools (usability, usefulness, and impact to decision making), these statements were collapsed to analyze for overall human performance with the tool. Results were not statistically significant.

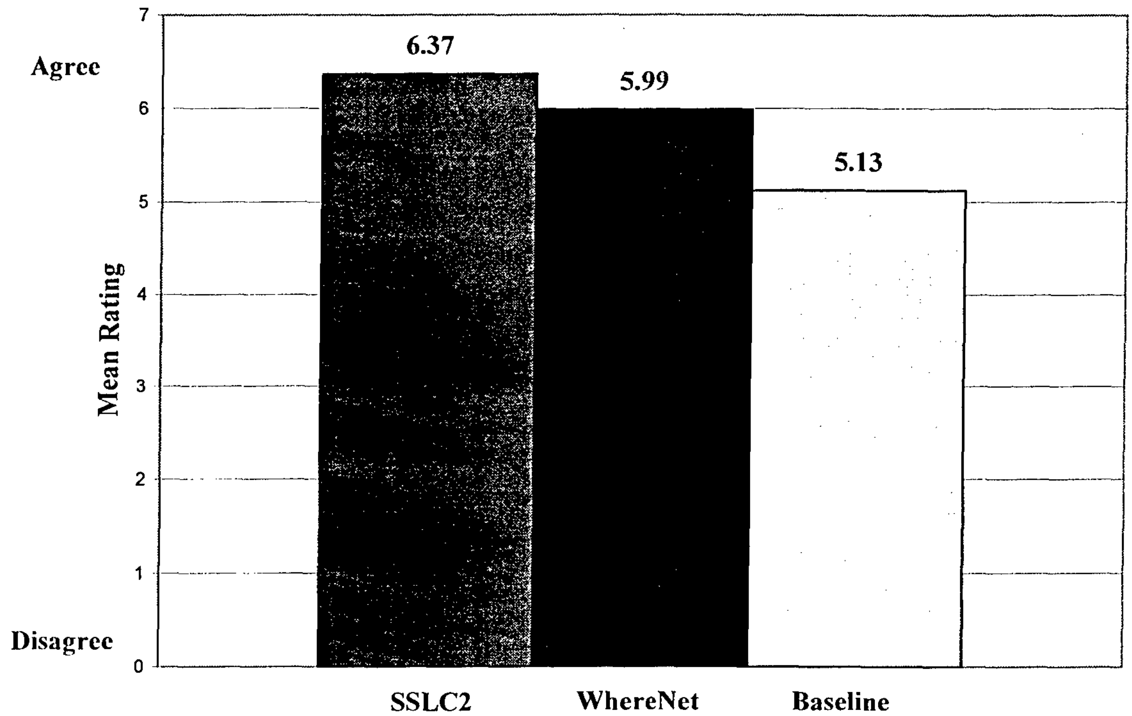


FIGURE 13: MEAN RATING SCORES COLLAPSED ACROSS ALL 15 RATING STATEMENTS

5.2.2 Post-Study Questionnaire Part 1: Ranking Results

Part 1 of the post-study questionnaires asked participants to rank order the three conditions for five purposes: monitoring resources, locating resources, identifying resource availability; tracking time associated with resources, and making the fix/swap decision. The rankings for all five questions were collapsed and analyzed for differences. Also, the mean rankings for each ranking question were evaluated across the three conditions. In all cases, an ANOVA with a criterion level of 0.05 was conducted with a Greenhouse-Geisser correction. Paired comparisons were also conducted when effects were significant using Tukey's test. Results are presented in Table 5.

When collapsing across the five statements there was a statistically significant difference between Smart Systems and WhereNet and between Smart Systems and Baseline (see Table 5 for mean rankings). There were no statistical differences between WhereNet and Baseline. Examining results for each ranking separately shows differences among the three conditions varied based on the ranking statement. There was a statistically significant difference between Smart Systems and WhereNet for 4 of the 5 statements (Monitoring, Locating, Tracking time and Fix/Swap) with Smart Systems

being ranked higher. There was a significant difference between Smart Systems and Baseline for 3 of the 5 statements (Monitoring, Locating and Identifying) with Smart Systems being ranked higher. Ranking was significantly different between WhereNet and Baseline only when making the Fix/Swap decision. In this case Baseline was ranked higher. These results suggest that there was little difference between Baseline and WhereNet conditions in terms of preference. Figure 14 shows the percentage that each condition was ranked either first, second or third across all five questions (225 rankings total). SSLC2 had 48% of the first place rankings, WhereNet had only 8% of first place rankings, and Baseline had 28%. WhereNet had 54% of the third place rankings and SSLC2 had only 5% of third place rankings.

TABLE 5: MEAN RANKINGS AND TUKEY GROUPINGS*

Preference Rating: 1=first Preference, 3= third preference	
Ranking Statement and F test	**Means and Tukey Groupings**
Monitoring Status of Resources F(1,14) = 8.34, **p** = .0119	SS = 1.33 (A) WN = 2.53 (B) BL = 2.13 (B)
Locating Resources F(1,14) = 5.44, **p** = .0351	SS = 1.40 (A) WN = 2.20 (B) BL = 2.40 (B)
Identifying Resource Availability F(1,14) = 3.90, **p** = .0683	SS = 1.47 (A) WN = 2.20 (A, B) BL =2.33 (B)
Tracking Time Associated with Resources F(1,14) = 11.20, **p** = .0048	SS = 1.33 (A) WN = 2.67 (B) BL = 2.00 (A, B)
Making Fix/Swap Decision F(1,14) = 9.86, **p** = .0072	SS = 1.53 (A) WN = 2.73 (B) BL = 1.73 (A)
Collapsing across all Ratings F(1,14) = 9.52, **p** = .0080	SS = 1.41 (A) WN = 2.47 (B) BL = 2.12 (B)

* Letters next to means indicate Tukey Groupings. Means with the same letter are not significantly different.

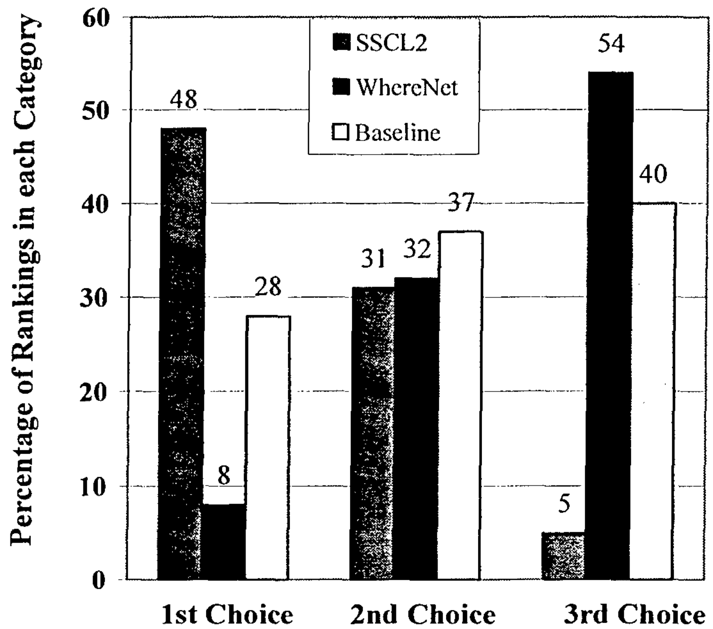


FIGURE 14: PERCENTAGES THAT EACH CONDITION WAS RANKED 1ST, 2ND, AND 3RD CHOICE

5.2.3 Summary of Ratings and Ranking Results

Table 6 summarizes the results related to five types of tasks. Results from the rankings indicated that SSLC2 was preferred to WhereNet and Baseline. When ranking the three conditions, there was only one difference between Baseline and WhereNet conditions. Baseline was ranked higher than WhereNet for making the Fix/Swap decision. However, WhereNet was rated higher than Baseline in four of the 15 rating statements (Table 4). These statements were related to location of equipment and personnel, availability of equipment, and improved resource utilization. It should be noted that WhereNet only provides information about location, not availability of resources. However location is sometimes an indication of availability, e.g., if personnel are located in the AMU the expeditor may assume they are available. For rating statements there were no differences between Smart Systems and WhereNet, yet Smart Systems was ranked higher in terms of preference. Users commented that they felt interacting with WhereNet was somewhat difficult; however they did like the ability to filter and sort resources.

TABLE 6: SUMMARY OF DIFFERENCES AMONG CONDITIONS

Task	Rankings	Ratings
Monitoring Resources	SSLC2 was preferred over WhereNet and Baseline	SSLC2 was rated higher than Baseline
Locating Resources	SSLC2 was preferred over WhereNet and Baseline	SSLC2 and Wherenet were rated higher than Baseline
Resource Availability	SSLC2 was preferred over Baseline	SSLC2 and WhereNet were rated higher than Baseline
Tracking Time	SSLC2 was preferred over WhereNet	SSLC2 were rated higher than Baseline
Resource Utilization based on knowledge of location	Not Applicable	WhereNet was rated higher than Baseline
Fix/Swap Decision	SSLC2 and Baseline were preferred over WhereNet	No difference for decision support

5.2.4 Post-Study Questionnaire Part 2: Decision Impacts

Post study questionnaire Part 2 requested participants to assign a rating indicating the importance of certain information on decisions. In the first half of the questionnaire participants rated 7 information elements (1-not at all important to 7-extremely important) on their fix/swap decision. The frequency data for this question is located in Section 3.1.1 Appendix B. Table 7 presents the average ratings for each data element.

TABLE 7: AVERAGE RATING FOR INFORMATION IMPORTANCE WHEN MAKING THE FIX OR SWAP DECISION

Data Element	Average Rating (1-7)
Today's flying schedule	7.00
Tomorrow's flying schedule	6.00
Weekly flying schedule	5.00
Monthly flying schedule	4.07
Flying schedule effectiveness metric (FSE)	4.36
Aircraft availability metric (AA)	6.00
Mission capable (MC) rate	5.07

Over half of the participants said the Aircraft Availability (AA) Metric was "extremely important" to the fix/swap decision. All of the participants said Today's Flying Schedule was "extremely important" when making the fix or swap decision. Other information that was "somewhat important" was Tomorrow's Flying Schedule and the

Weekly Flying Schedule. Additional data points were Flying Schedule Effectiveness (FSE) Rate, Monthly flying Schedule, and MC Rate which mainly fell into the "slightly important" or "neutral categories."

The second part of the questionnaire asked participants to rate how various decisions they make impact FSE, AA, and MC rates. Table 8 provides a summary of the average ratings. Frequency information can be found in Section 3.1.1 Appendix B.

TABLE 8: AVERAGE RATING FOR HOW DECISIONS IMPACT FSE, AA AND MC RATES

Data Element	Average Rating (1-7)
What Personnel should be assigned to maintenance tasks?	5.86
Fix or Swap?	6.36
Should the flight be delayed?	6.36
Should we CANN?	6.00
Which aircraft should be assigned to which sortie?	6.21
How should aircraft be assigned for the week?	5.36
How will aircraft be assigned for the month?	4.46
How should today's flying schedule be changed?	6.15

The fix/swap decision was ranked highest with nine respondents saying it was "extremely important" in impacting metrics. Additional "extremely important" decisions were: How should today's flying schedule be changed; should the flight be delayed; and which aircraft should be assigned to which sorties? Most participants rated the Monthly schedules as slightly important (seven of thirteen) or neutral (four of thirteen). These results are important for planning what information and decisions a future decision support tool should focus on.

5.2.5 Post-Study Questionnaire Part 3: Data Elements

This part of the questionnaire asked participants to rate on a scale of 1 to 7, the importance of data elements that would be available in an electronic decision support tool. The data elements were broken into five categories: Aircraft, Personnel, AGE, Supply, and Other. They were also asked to write in any data elements they considered important. Table 9 provides the average ratings for each data element. (See Section 3.1.2 in Appendix B for frequency information.)

TABLE 9: AVERAGE IMPORTANT RATING FOR DATA ELEMENTS IN A DECISION SUPPORT TOOL

DATA ELEMENT	Average Rating (1 -7)
AIRCRAFT	
Location of aircraft	6.64
Current status of aircraft (FMC, NMC, PMC)	7.00
781 Discrepancies	6.5
CAMS 380 list of jobs	5.36
Aircraft hours	4.07
Engine hours and cycles	3.92
Time since last Phase/ISO inspection	4.5
Aircraft configuration	6.75
Aircraft maintenance history	4.57
Monthly aircraft scheduled maintenance	5.21
Weekly aircraft scheduled maintenance	5.86
Weekly flying schedule	6.00
Monthly flying schedule	4.71
PERSONNEL	
Location of personnel resources	6.69
Weekly personnel schedules	5.5
Monthly personnel schedules	4.43
Personnel qualifications Rank	5.78
Personnel qualifications Specialty	6.43
Personnel qualifications Skill level (3,5,7)	6.71
Personnel qualifications Certifications	6.64
Special certification rosters (RedX, ER, intake, etc)	6.86
Personnel status	6.46
AGE	
Location of AGE and other equipment	6.00
Status of AGE equipment (FMC, NMC)	6.14
Fuel level on powered equipment	5.29
Level of liquid oxygen	6.36
Battery level on equipment	4.64
107 requests	3.91
SUPPLY	
Location of supplies	6.00
Bench Stock	5.86
Status of supplies	6.14
Location of MICAP supply	6.29
Status of MICAP supply	6.38
350 tag	4.42
OTHER	
Weather	6.57
Squadron unit monthly analysis indicators report	4.33

Under the category of Aircraft, participants indicated 781 Discrepancies, Aircraft Configuration, Current Aircraft Status and Aircraft Location were "extremely important" while CAMS 380 Job Listings, Monthly Flying Schedule, Weekly Scheduled

Maintenance and Weekly Flying Schedules were "slightly important" or "somewhat important." These data points are consistent with participant comments during the study. Aircraft information rated "slightly important," "somewhat important" or "not important at all" were Aircraft Maintenance History, Engine Hours and Cycles, Monthly Scheduled Maintenance, and Time since last Phase/Inspection Operations (ISO) Inspection.

AGE related data elements including Fuel Level, Liquid Oxygen Level, AGE and Equipment Location and AGE Status were "somewhat important" and "extremely important" while 107 Request and Battery Levels were not overwhelmingly important to the participants.

Participants ranked personnel data elements associated with location, schedule, and qualifications. Participants overwhelmingly ranked personnel location, specialties, certifications, skill levels and rosters as "extremely important" information points for doing their jobs. This data element grouping was rated the highest compared to AGE or supply information. This data reinforces many comments during the field test relating to difficulty in finding the right people at the right time.

Participants frequently asked questions about supply during the study and their data rankings indicated Mission Capability (MICAP) and Supply Status were "extremely important." MICAP and Supply Location and Bench Stock were rated "somewhat important."

5.3 COMFORT LEVEL

Before beginning each condition, immediately following practice, the participants, were asked to rate their comfort level with the technology on a scale of 1-7, with 7 being the most comfortable. The comfort levels were averaged across participants within both groups, Fighter and Airlift. A t-test was conducted across all three conditions, collapsing across aircraft type. Data were also analyzed by aircraft type using a t-test. Significance criterion was set at 0.05. Figure 15 illustrates the data.

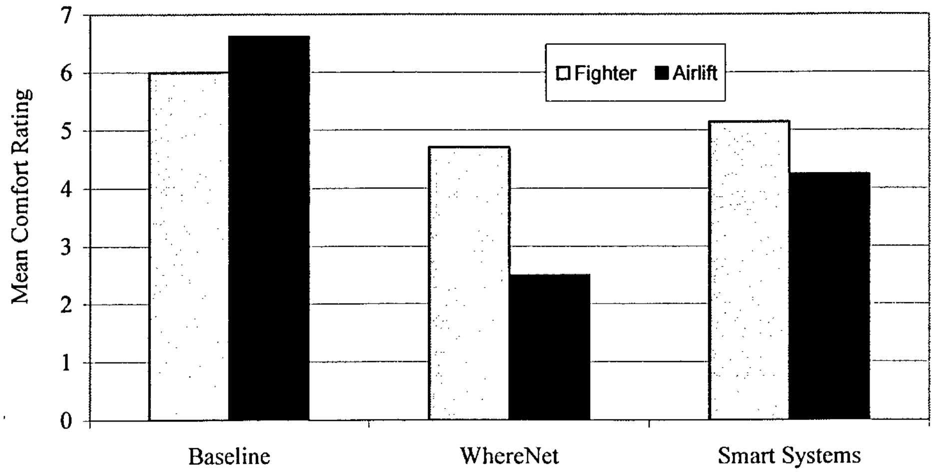


FIGURE 15: MEAN COMFORT RATING

There was a statistically significant difference among all three conditions t (43) = 2.021, ($p \leq 0.05$). As expected most participants provided the highest ratings (were most comfortable) in the baseline condition using a radio. Participants were more comfortable with SSLC2 after initial training than with WhereNet. Analyzing the data by aircraft type, there was a statistically significant different between WhereNet and Baseline comfort levels for the Fighter participants (t (22) = 2.093, ($p \leq 0.05$). For Airlift participants, there was a statistically significant difference among all three comfort levels.

5.4 TIME TO FIX

During the experiment participants were asked to provide an estimate of the time to fix the problem aircraft. This estimate was provided during the first portion of the scenarios when making the fix/swap decision. Not all participants provided an estimate. Out of 45 possible data points, eight were missing. For the remaining data points, the mean time to fix estimate was determined for the three conditions. The mean time in minutes were Baseline X = 343.85; WhereNet X = 354.54; SSCL2 X = 440.00. A t-test was conducted to exam the differences between means. There was a statistically significant difference between the SSCL2 and Baseline Conditions t (37) = 2.034, ($p <$ 0.05). There were no other significant differences. SSLC2 provided time to fix values for the participant. For the Baseline and WhereNet conditions, participants had to compute the information or they specifically requested it from an outside source such as

the specialist over the radio. The variance around the means for the Baseline and WhereNet conditions is quite high (Std Dev = 130 for Baseline and 135 for WhereNet) compared to SSLC2 as would be expected (Std Dev = 62). When participants had to estimate fix times, the times were shorter than those specified in SSLC2. It should be noted that SSCL2 fix times were determined by the SMEs and AFRL/HEAL Functionals.

5.5 TIME TO SITE

During each scenario participants made decisions about resources, both equipment and personnel. They had to choose and locate a resource and were asked to give an estimate of the time it would take for the resource to reach the problem site (time to site).

There were a total of 69 data points available for this analysis, with 23 data points in each condition. The mean time to site estimates in minutes were: Baseline X = 6.52; WhereNet X = 6.74; and SSLC2 X = 3.89. A t-test was conducted to determine differences between the three conditions.

There was a statistically significant difference between the SSLC2 and WhereNet Conditions t (69) = 1.996, ($p < 0.05$). There were no other significant differences. The variance related to estimates were greater in the Baseline and WhereNet conditions (Std Dev Baseline = 4.48; Std Dev WhereNet = 4.50) compared to SSLC2 (Std Dev = 2.18). SSLC2 calculated time to site with a straight line estimate. Participant's estimates were primarily based on their experience that it should not take more than 5 to 10 minutes for someone or something to arrive once requested. Most participants indicated verbally that the time for resources to arrive would not change their Estimated Time to Completion (ETIC) or time to fix estimates.

5.6 VERBAL PROTOCOL ANALYSIS

Participants were asked to think aloud during each scenario. Their verbal statements were recorded and notes were also taken in real time. The verbal information for fifteen subjects was evaluated, across all three conditions resulting in analysis of 45 scenarios. (Note that data analysis of questionnaires had data for fourteen participants because one participant did not complete all questionnaires. However, the participant did complete all scenarios so the data were included in this analysis.) The data were analyzed in several

different ways. First the information was broken into steps. For each step, the verbal information was dissected into six categories. Section 3.2 of Appendix B, Data Collection illustrates the data table used. The first category is **Information.** This category refers to the type of information the participant was seeking, distributing or working with during the step. The second category is **Source**, which refers to where they were seeking the information. The third category is **Destination**, referring to where the participant sent or distributed the information. The fourth category is **Decision** which indicates what decision they were working on. The fifth category is **Time**, which was used to input the time to site or time to fix information that participant provided during the scenario. The sixth category is **Process** which is a description of steps or the process the participants were taking. Data from each of these steps was analyzed as detailed below.

5.6.1 Information

The types of information the participants used during the task were determined and a frequency count was tabulated showing how often the information was referred to or used across all fifteen subjects and three conditions (45 scenarios). Section 3.2.1 in Appendix B, Data Collection provides the frequency count data and categories of information. The data helps to determine the type of information the participants needed to complete the tasks. Because participants were specifically instructed to provide time to site and time to fix information as well as find equipment and personnel resources these types of information have the highest frequency counts. If these data were not specifically requested, they may not have referred to them as often.

5.6.1.1 Equipment Resources

Equipment was broken into four categories. 1) Equipment allocation – participants allocated or requested a piece of equipment. 2) Equipment availability, 3) Equipment location, and 4) Equipment movement. The frequency counts are summarized in Table 10 below.

TABLE 10: EQUIPMENT INFORMATION ANALYSIS

Information	Baseline	WhereNet	SSLC2	Total
Equipment Allocation	15	15	2	32
Equipment Availability	10	6	2	18
Equipment Location	4	24	15	43
Equipment Movement	0	1	0	1

For the categories of equipment allocation and availability there are similar frequency counts between Baseline and WhereNet conditions, which are both higher than SSLC2. SSLC2 provides allocation automatically and selects equipment based on location and availability. Therefore, SSLC2 reduced the number of times Expeditors had to request or find equipment. In terms of equipment location, participants in the Baseline condition did not refer to equipment location. In WhereNet and SSLC2 they used the computer systems to search for specific equipment. WhereNet had the largest frequency count for this information. In all scenarios participants were required to replace a piece of equipment that had malfunctioned or gone missing. In the Baseline condition they called AGE and requested the equipment. Baseline participants were not concerned with equipment location.

When using WhereNet and SSLC2 the RFID/RTLS technology and software allowed participants to see these resources. Most participants commented they did not want to be responsible for finding a piece of equipment as demonstrated in the WhereNet and SSLC2 conditions. They believed this specific job or task was assigned to a different individual or group on the maintenance team, usually AGE. They suggested AGE would be interested in RFID/RTLS location information for equipment. Some participants indicated they liked knowing where the resources were, but searching would take them away from more important tasks. It is important not to add additional tasks for the Expeditors. It is much faster for them to call for the equipment and they will not use the system if it is not just as easy as their current techniques. They did not use equipment location to provide them with situation awareness information. For future evaluations when multiple problems are presented simultaneously the impact of moving resources may be more important and equipment location and status information might be used by Expeditors as a situation assessment tool. Participants said status and availability

information specifically for low density high demand equipment would be more beneficial than equipment location in determining equipment allocation.

WhereNet and SSLC2 provided an update that showed equipment moving. While this has the potential to provide situation awareness information, this was not something that participants used during the scenarios. The Expeditors are typically moving on to a different task and assume the equipment will arrive once requested.

5.6.1.2 Personnel Resources

For personnel resources there are high frequency counts under Baseline and WhereNet for personnel allocation. Personnel availability is also higher for Baseline compared to WhereNet and SSLC2 (Table 11). Location was similar across the three conditions with higher frequencies under WhereNet and SSLC2 because participants could search for people using the software. In the Baseline condition they called others to find people. Many participants commented that finding personnel was one of their biggest problems. They stated a great deal of time was wasted looking for people and believed the ability to find personnel would be very beneficial. They expressed concerns about how personnel would respond to the concept of tagging and thought that for civilians at Continental United Status (CONUS) base settings it may be a problem; however it was not an issue for deployment.

TABLE 11: PERSONNEL INFORMATION ANALYSIS

Information	Baseline	WhereNet	SSCL2	Total
Personnel Allocation	10	15	2	27
Personnel Availability	17	5	6	28
Personnel Location	8	18	12	38
Personnel Qualifications	1	0	0	1

Personnel qualifications was another area in which participants thought information was needed, but they did not refer to it in the scenarios. One reason may be that in most cases the scenarios did not require any very specific qualifications beyond crew chief. Also, as soon as they realized it was not available from any source in the study they did not request it. While they did not refer to this often in the scenarios they did comment the information was important. In the post questionnaire when asked to rate the

importance of information, eleven of fourteen rated personnel skill level as a 7 (extremely important).

5.6.1.3 Other Information

Another high frequency item was Aircraft Problem. This category refers to information about the other Non Mission Capable (NMC) aircraft on the flightline, not the aircraft they were currently working in the scenario. Participants asked for more information related to the problems to determine if any of those aircraft would be available for a swap. This request was made more frequently under WhereNet and SSLC2 conditions than Baseline. The reason for this difference is not clear. However, it does relate to situational awareness. Participants were attempting to find more information about the overall flightline to help them make their decision. This was the case even under the SSLC2 condition where a recommendation for which aircraft to swap with was provided.

Other high frequency information items were aircraft status (which includes any aircraft on the flightline), current time, ETIC, take-off time, and task assignment. Task assignment refers to when they assigned a specific task (e.g. calling for a weapons download, or defuel). Swap was also high frequency because they were asked to make the fix/swap decision and in most cases the scenario required a swap.

5.6.2 Source

Where the participants sought information was documented and the frequency was tabulated. Section 3.2.2 of Appendix B, Data Collection illustrates this data. In the Baseline and WhereNet conditions information was primarily sought from AGE, AMU Dispatch, the Specialist, and status/schedule sheet. If participants were confused they would sometimes request information or clarification about the scenario via the Principal Investigator. The category labeled "self" indicates they used experience and often computed the time to site and time to fix mentally to come up with those data points. The data were not readily available without this mental calculation. Mental calculation was not necessary in SSLC2, resulting in low frequency count under that category.

Under the WhereNet condition, participants referred to the WhereNet screens 41 times, yet they also sought information from the same resources as Baseline, often in the

same frequency. This is not surprising because WhereNet only provides resource location. All other information needed to make decisions must be found from other resources. Thus WhereNet is unlikely to reduce workload or to enhance decision support.

In the case of SSLC2, all information was provided on the system so participants referred to fewer additional sources. However, the simulation scenario required the resource problems to be called in via radio by the SME acting as a specialist after the first initial fix/swap decision. Sometimes the participant forgot what the specialist requested and called back. The information source for SSLC2 was specified by screen. They sought their information from the overview screens, the problem schedule screen, and the comparison screens. They also used select plan in order to make the fix/swap decision. SSLC2 significantly reduced the radio communication traffic as participants were able to look for information on the system rather than via radio. SSLC2 provided the Expeditor a tool that centralizes information and has potential for increasing situation awareness. If a great deal of the information must be sought via radio, paper sheets, visual input, etc, participants must integrate all the information in their mind. SSLC2 reduces the need for mental integration of information.

5.6.3 Destination

Frequencies were determined for Destination, which refers to where the participant sent or distributed the information and can be found in Section 3.2.3 of Appendix B, Data Collection. In the Baseline and WhereNet conditions, participants sent information to 10 sources, with a count of 65 and 70 times information was sent. The primary destinations were AGE, AMU dispatch, MOC, and the Specialist. For the SSLC2 condition, only AGE, AMU dispatch and MOC were destination sources for radio calls, and the frequency count was 4. Again, the WhereNet and Baseline conditions required participants to send tasks and information to various destinations via the radio, whereas SSLC2 did this automatically.

5.6.4 Cognitive Task Analysis

An objective of the Scientific Study was to validate the cognitive models presented in Section 3. This study focused specifically on one Expeditor task, "Assess aircraft status", focusing on the fix or swap decision process. Information from the verbal protocol under

the Process category was analyzed and results were compared to the cognitive model created from the initial data collection via interviews.

A table was created indicating the general steps participants used during the Scientific Study for both Fighter and Airlift. Once the table was developed, the steps and the order of steps each participant described in their verbal protocol were placed in the table. The frequencies for the various task steps were then calculated. The number of times a step was the first step, second step, third step, etc. was also counted. Tables 12 and 13 provide the frequency counts for the various steps for Fighter and Airlift participants during the initial scenario trigger requiring participants to determine the problem and decide whether to fix or swap.

TABLE 12: AIRLIFT FREQUENCIES FOR EACH CONDITION

Task List	Frequency			Task List	Frequency		
	BL	WN	SS		BL	WN	SS
Begin analysis of situation			1	Compare time to fix to flight schedule			
• Hazard/safety		1		1) Current time	1	1	1
• Flares/weapons	2	1		2) Take off time	3		3
• Hanger	2			3) Will it make flight?	2		
• Parts	2		1	Compare time to swap			4
• Weather	1	2	1	Decide to swap	9	9	8
• Fuels	1		1	• Determine aircraft to swap	9	9	4
o Download necessary?	1	3		• Update ProSuper	3	2	
o availability				• Update MOC	6	3	1
• Fuel barn location			1	• Get Job Number		2	
• Jack (time, outside?)	1	2		• Select Swap Recommendation	NA	NA	6
• Aircraft configuration		1		Begin Fix		1	
• Cargo/mission	1		1	• Defuel	3	3	1
• Other broken a/c status update		4	3	• Flares (Airlift only)	2	1	
Determine Time to Fix				• Jacks	1	3	
• From specialist or crew chief	6	6	2	• Tow Team	5		1
• Self estimate	4	3		• Review time to site	1	1	1
• SSLC2	NA	NA	6	• Weapons (fighter only)			
				• Egress (fighter only)			
				Review how swap affects overall schedule			3

TABLE 13: FIGHTER FREQUENCIES BY CONDITION

Task List	Frequency			Task List	Frequency		
	BL	WN	SS		BL	WN	SS
Begin analysis of situation				Compare time to fix to flight schedule			
• Hazard/safety				4) Current time	1		
• Flares/weapons				5) Take off time	3	1	5
• Hanger	1	1		6) Will it make flight?			
• Parts	1			Compare time to swap			2
• Weather	1	1		Decide to swap	6	6	6
• Fuels				• Determine aircraft to swap	6	6	1
o Download necessary?				• Update ProSuper		1	
o availability				• Update MOC	4	4	
• Fuel barn location				• Get Job Number			
• Jack (time, outside?)				• Select swap recommendation	NA	NA	6
• Aircraft configuration		1		Begin Fix			
• Cargo/mission				• Defuel	1	1	
• Other broken a/c status update				• Flares (Airlift only)			
Determine Time to Fix	2	2		• Jacks	1	2	
• From specialist or crew chief	6	3		• Tow Team	2	3	
• Self estimate	2			• Review time to site			
• SSLC2	NA	NA	6	• Weapons (fighter only)	4	3	
				• Egress (fighter only)	1		

Task List	Frequency			Task List	Frequency		
	BL	WN	SS		BL	WN	SS
				Review how swap affects overall schedule	1	1	1

To visualize the process steps, including order, flow diagrams were created for each condition under each aircraft group type (Fighter and Airlift). A major task is illustrated as a square with the subtasks making up each task indicated as circles within the square. The legend for each subtask is at the bottom of the figure. Each colored line represents a different subject. The starting location is indicated by the thickest line for each participant. It must be noted while each step is delineated in the flow, participants often made decisions simultaneously. For example, to specify they had decided to swap, they might say "I will swap with tail 451". This was indicated in the diagram as a line going to the Swap decision box first, then the subtask of "determine a/c to swap". A discussion of the process patterns by aircraft type and the flow diagrams are presented below. Figures 16-18 depict Fighter participants' process flows by technology condition while Figures 19-21 depict Airlift participants' process flows by technology conditions.

5.6.4.1 Fighter Participants

Fighter participants using SSLC2 did not evaluate the specific aircraft problem in depth. As indicated by Figure 16 and the frequency counts, there are no references in their protocols related to pre-decision analysis when using SSLC2. In general, the process was to look at the time to fix, determine take-off time and immediately make the fix/swap decision, and use "select plan" to execute the swap. One participant determined which aircraft to swap with before going with the recommended plan. Two subjects also looked at swap time. No participants began the fix before making the swap decision. Four of the six subjects made the swap decision within three steps, and two within four steps.

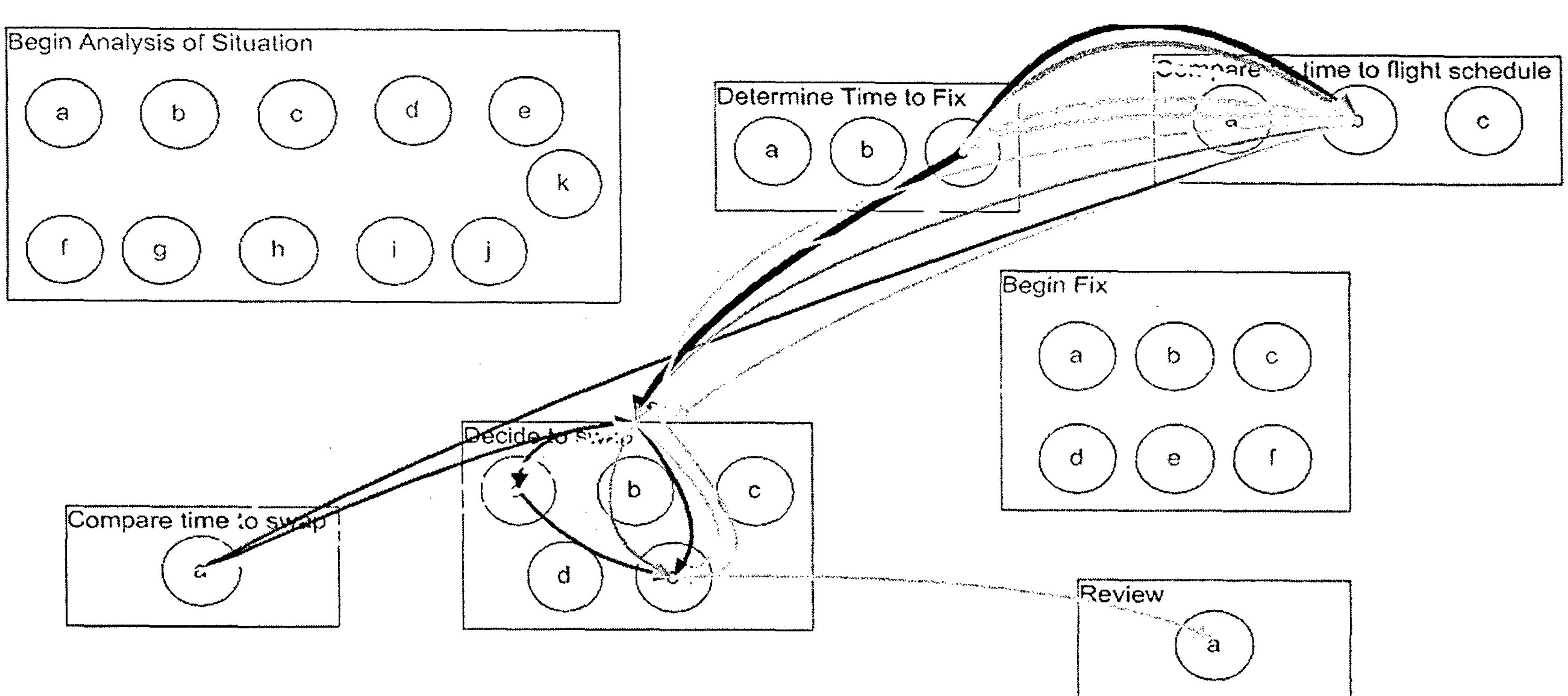
Recall that SSLC2 gave the participant the current schedule, time to fix, time to swap and a recommendation for which aircraft to swap with. They were not required to determine individual steps toward the fix or mentally calculate tasks times to determine a total fix time. They did not need to use the radio to send out messages to begin the fix, resulting in no frequency counts in the Begin Fix task. Their level of communication using the radio was reduced compared to Baseline and WhereNet conditions. Participants seemed to trust what SSLC2 recommended. Only one participant in this group went back to consider how the swap might affect the overall schedule.

Process flow patterns for WhereNet and Baseline conditions are different from SSLC2. Under both these conditions the aircraft status and flight schedules were available on their paper status sheets. WhereNet provides resource location but no other information related to the fix or swap. Because these two conditions are similar to how they currently work on the flightline we would expect the WhereNet and Baseline conditions to be very similar. Yet it appears that participants behaved somewhat differently.

For the WhereNet condition three of the six subjects began by determining the time to fix based on information from the specialist. One participant immediately made the decision to swap based on his experience. One participant began an analysis of the situation. One participant started by requesting a tow team before requesting time to fix. Five of the six participants made the swap decision within the first three steps. All participants had to determine which aircraft to swap with. One participant reviewed the situation after the decision. Two of the six began at least one step in the fix process before making the swap decision. Participants did not discuss the time to swap.

In the Baseline condition the processes seemed to vary more by participant. For the Baseline condition two of the participants made the fix/swap decision within three steps, one in four steps and two within five steps. Three of the subjects began with some analysis of the situation, and four subjects began the fix process. Three of the six began the fix process before making the swap decision.

It appears the slight difference between WhereNet and Baseline is that more participants in Baseline performed a pre-analysis and began fix tasks. More Baseline participants referred to the take-off time as well. These differences may be due to the fact participants were more comfortable in the Baseline condition. When using WhereNet they may have spent their time locating resources without gaining much information necessary for the specific decision. Again, participants did not discuss the time to swap.



Fighter SSLC2

Begin Analysis of Situation
a. hazard safety
b. flares/weapons
c. hanger
d. parts
e. weather
f. fuel
g. fuel barn location
h. jack
i. aircraft configuration
j. cargo/mission
k. other broken a/c status update

Determine Time to Fix
a. From specialist or crew chief
b. self estimate
c. smart systems

Compare fix time to flight schedule
a. current time
b. take off time
c. will it make flight?

Note: Starting point lines are indicted by the thickest line.

Compare time to swap
a. compare swap time

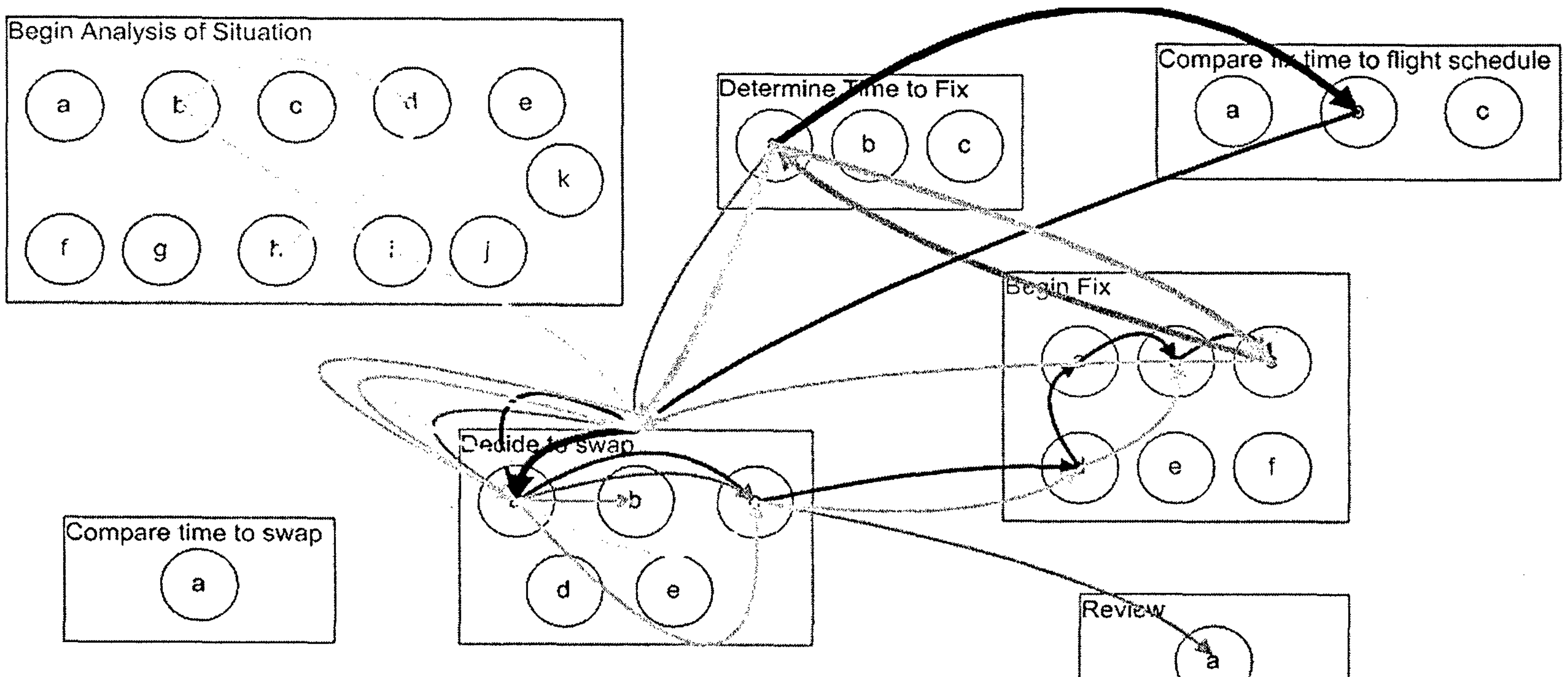
Participant Color Code
1
2
3
4
5
6

Decide to swap
a. determine a/c to swap
b. update prosuper
c. update MOC
d. get job number
e. select swap recommendation

Begin Fix
a. defuel
b. jacks
c. tow team
d. review time to site
e. weapons
f. egress

Review
a. review how swap affects overall schedule

FIGURE 16: FIGHTER PARTICIPANTS' PROCESS FLOW USING SSLC2



Fighter WhereNet

Begin Analysis of Situation
a. hazard safety
b. flares/weapons
c. hanger
d. parts
e. weather
f. fuel
g. fuel barn location
h. jack
I. aircraft configuration
j. cargo/mission
k. other broken a/c status update

Determine Time to Fix
a. From specialist or crew chief
b. self estimate
c. smart systems

Note: Starting point lines are indicted by the thickest line.

Compare fix time to flight schedule
a. current time
b. take off time
c. will it make flight?

Compare time to swap
a. compare swap time

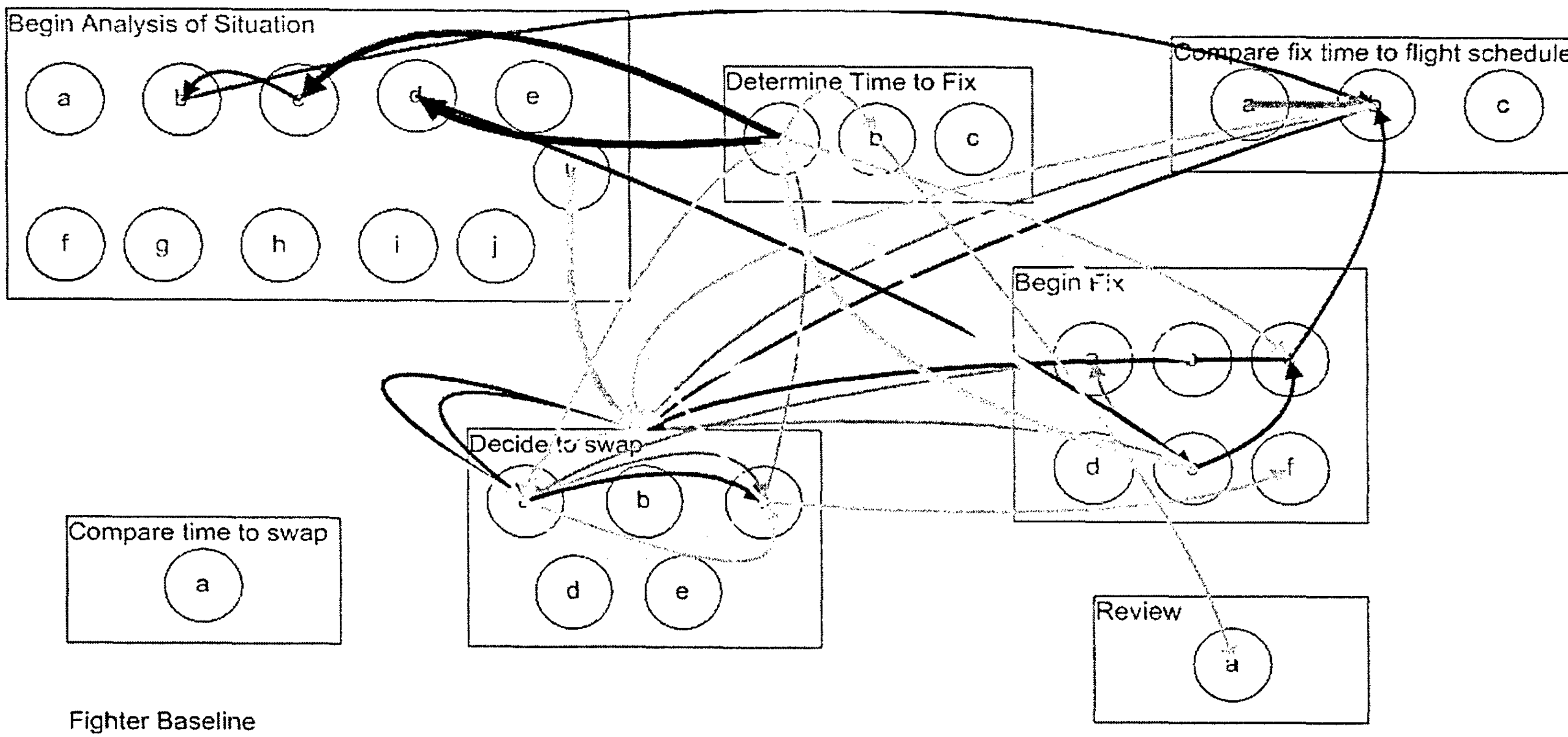
Participant Color Code
1
2
3
4
5
6

Decide to swap
a.determine a/c to swap
b. update prosuper
c. update MOC
d. get job number
e. select swap recommendation

Begin Fix
a. defuel
b. jacks
c. tow team
d. review time to site
e. weapons
f. egress

Review
a. review how swap affects overall schedule

FIGURE 17: FIGHTER PARTICIPANTS' PROCESS FLOW USING WHERENET



Begin Analysis of Situation
a. hazard safety
b. flares/weapons
c. hanger
d. parts
e. weather
f. fuel
g. fuel barn location
h. jack
I. aircraft configuration
j. cargo/mission
k. other broken a/c status update

Determine Time to Fix
a. From specialist or crew chief
b. self estimate
c. smart systems

Compare fix time to flight schedule
a. current time
b. take off time
c. will it make flight?

Note: Starting point lines are indicted by the thickest line.

Compare time to swap
a. compare swap time

Participant Color Code
1
2
3
4
5
6

Decide to swap
a.determine a/c to swap
b. update prosuper
c. update MOC
d. get job number
e. select swap recommendation

Begin Fix
a. defuel
b. jacks
c. tow team
d. review time to site
e. weapons
f. egress

Review
a. review how swap affects overall schedule

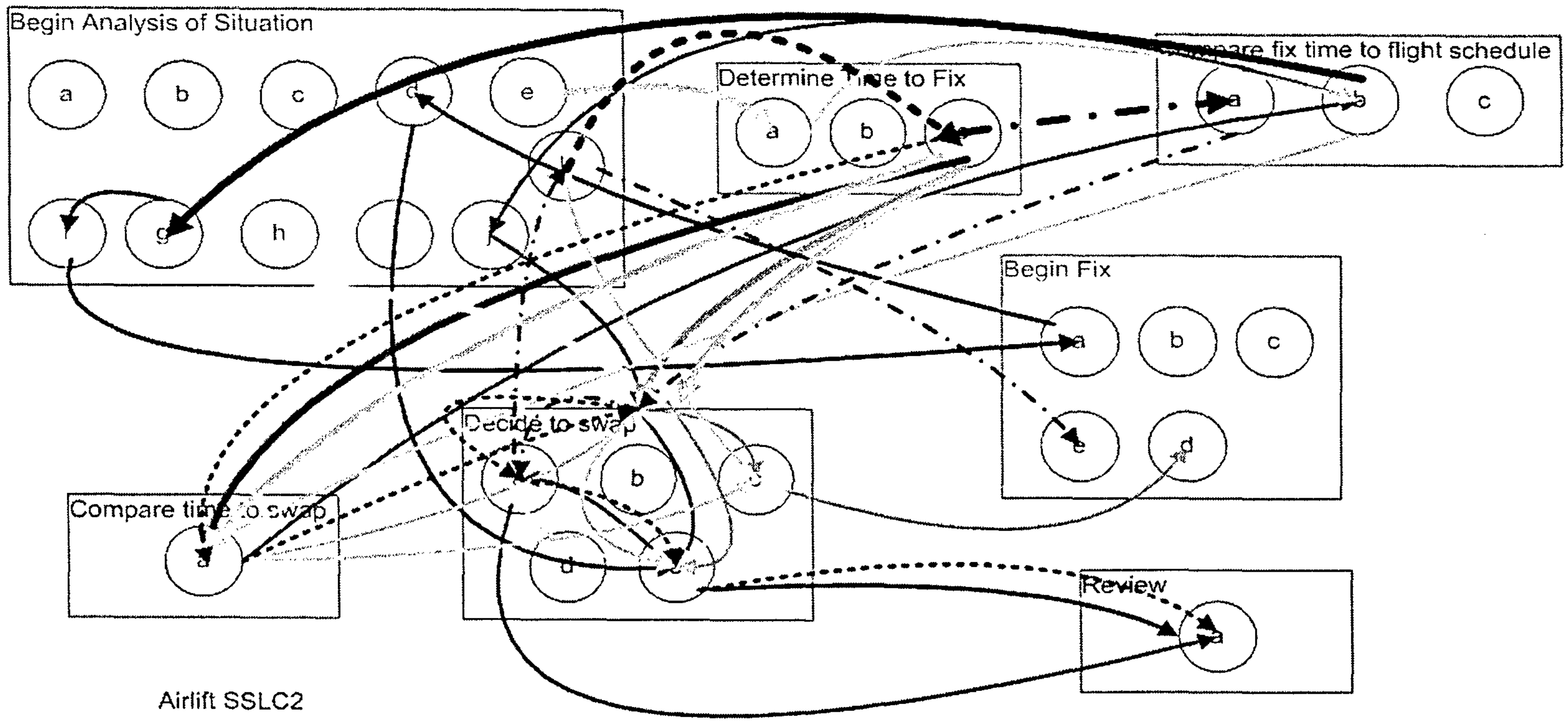
FIGURE 18: FIGHTER PARTICIPANTS' PROCESS FLOW USING BASELINE

5.6.4.2 Airlift Participants

As with Fighter participants the general process for Airlift participants while using SSLC2 was to locate the time to fix, compare time to swap and then make the fix/swap decision using "select plan". Six of the nine participants made the fix/swap decision within three steps. Five participants considered at least one item related to pre-analysis of the situation before making the fix/swap decision, although only one participant analyzed more than one item (Figure 19). Only one of the nine participants began a portion of the fix task before making the fix/swap decision. Three participants reviewed the situation after making the decision. Three participants compared time to swap. Although SSLC2 provides a swap recommendation at least four of the participants specified or mentioned which aircraft to swap. Two of those four considered it before choosing "select plan" and two after choosing "select plan".

In the WhereNet and Baseline conditions (Figures 20 and 21), participants spent more time doing pre-analysis of the situation than when they used SSLC2. They also spent time beginning the fix. For the WhereNet condition, five of the nine participants made the fix/swap decision within three steps. Six of the nine participants did some pre-analysis before making the decision. Two of the nine began the fix before making the swap decision. Participants did not discuss time to swap.

The Baseline condition was similar to WhereNet with four of the nine making the fix/swap decision within three steps. Five of the nine did some pre-analysis before making the decision and three began the fix before making the swap decision. As with WhereNet, participants did not discuss time to swap.



Begin Analysis of Situation
a. hazard safety
b. flares/weapons
c. hanger
d. parts
e. weather
f. fuel
g. fuel barn location
h. jack
I. aircraft configuration
j. cargo/mission
k. other broken a/c status update

Determine Time to Fix
a. From specialist or crew chief
b. self estimate
c. smart systems

Compare fix time to flight schedule
a. current time
b. take off time
c. will it make flight?

Compare time to swap
a. compare swap time

Decide to swap
a. determine a/c to swap
b. update prosuper
c. update MOC
d. get job number
e. select swap recommendation

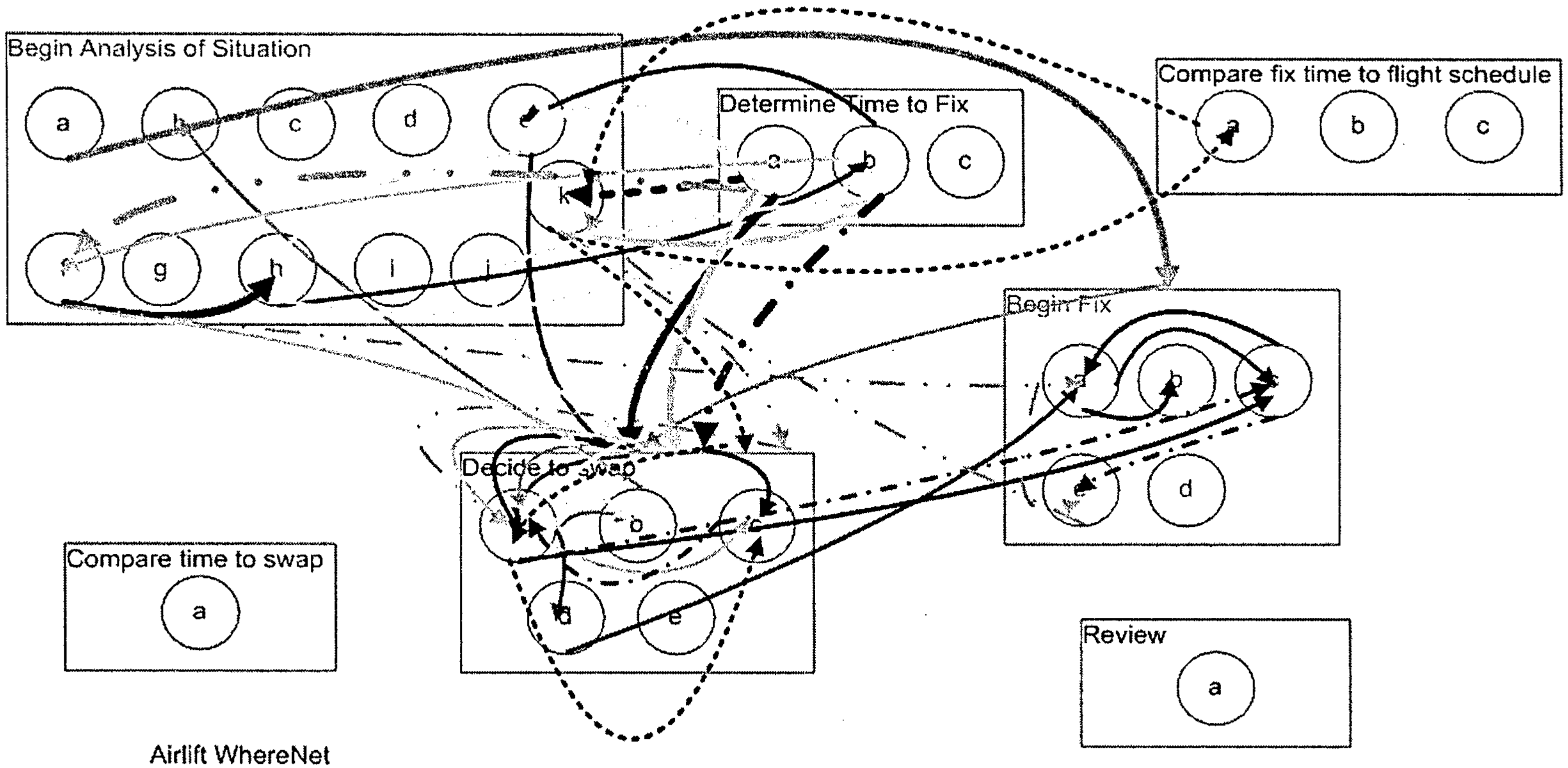
Begin Fix
a. defuel
b. flares
c. jacks
d. tow team
e. review time to site

Review
a. review how swap affects overall schedule

Note: Starting point lines are indicted by the thickest line.

Participant Color Code
1
2
3
4
5
6
7
8
9

FIGURE 19: AIRLIFT PARTICIPANTS' PROCESS FLOW USING SSLC2



Begin Analysis of Situation
a. hazard safety
b. flares/weapons
c. hanger
d. parts
e. weather
f. fuel
g. fuel barn location
h. jack
I. aircraft configuration .
j. cargo/mission
k. other broken a/c status update

Determine Time to Fix
a. From specialist or crew chief
b. self estimate
c. smart systems

Compare fix time to flight schedule
a. current time
b. take off time
c. will it make flight?

Note: Starting point lines are indicted by the thickest line.

Compare time to swap
a. compare swap time

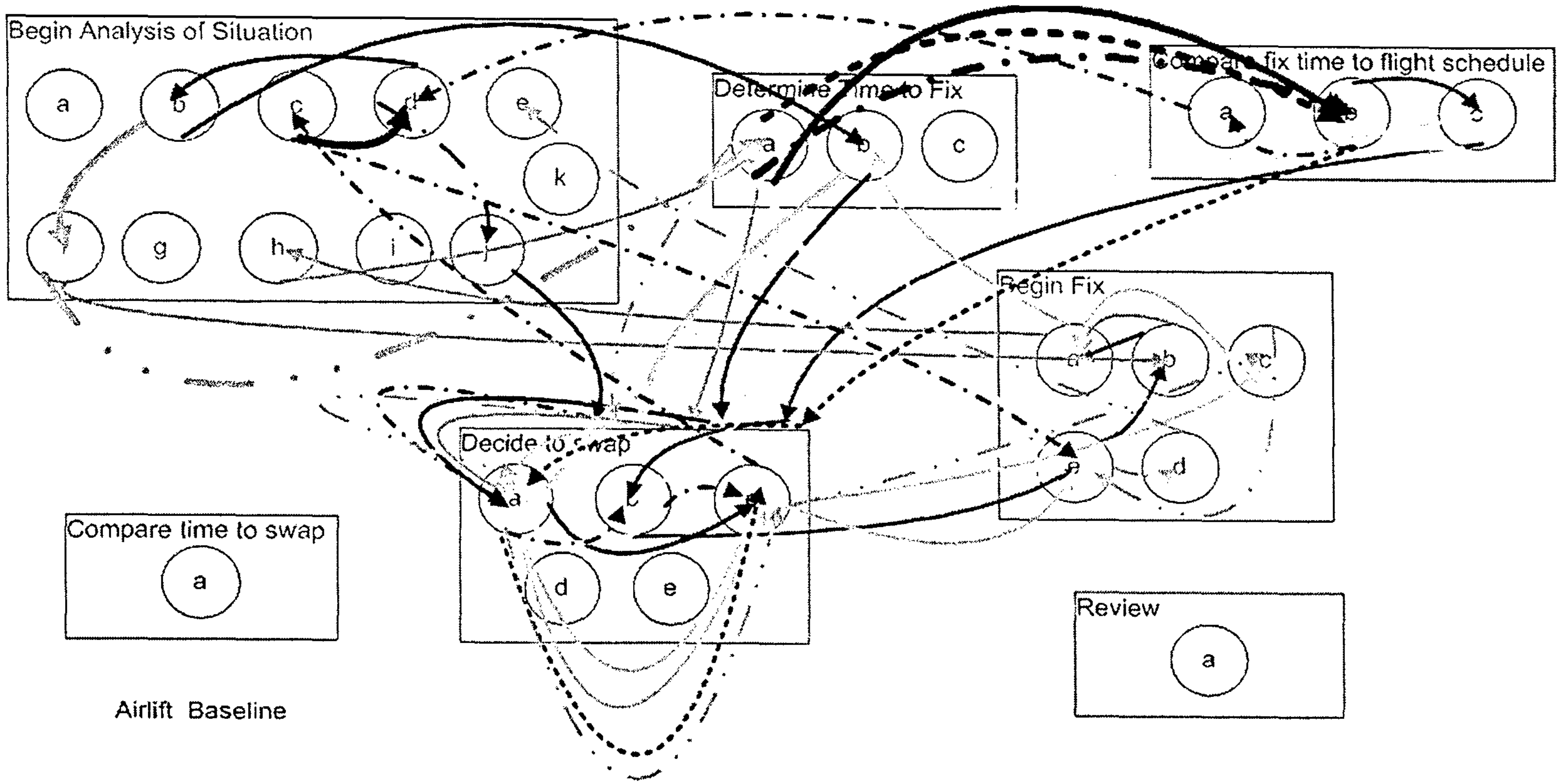
Participant Color Code
1
2
3
4
5
6
7
8
9

Decide to swap
a.determine a/c to swap
b. update prosuper
c. update MOC
d. get job number
e. select swap recommendation

Begin Fix
a. defuel
b. flares
c. jacks
d. tow team
e. review time to site

Review
a. review how swap affects overall schedule

FIGURE 20: AIRLIFT PARTICIPANTS' PROCESS FLOW USING WHERENET



Begin Analysis of Situation
a. hazard safety
b. flares/weapons
c. hanger
d. parts
e. weather
f. fuel
g. fuel barn location
h. jack
I. aircraft configuration
j. cargo/mission
k. other broken a/c status update

Determine Time to Fix
a. From specialist or crew chief
b. self estimate
c. smart systems

Note: Starting point lines are indicted by the thickest line.

Compare fix time to flight schedule
a. current time
b. take off time
c. will it make flight?

Compare time to swap
a. compare swap time

Participant Color Code
1
2
3
4
5
6
7
8
9

Decide to swap
a.determine a/c to swap
b. update prosuper
c. update MOC
d. get job number
e. select swap recommendation

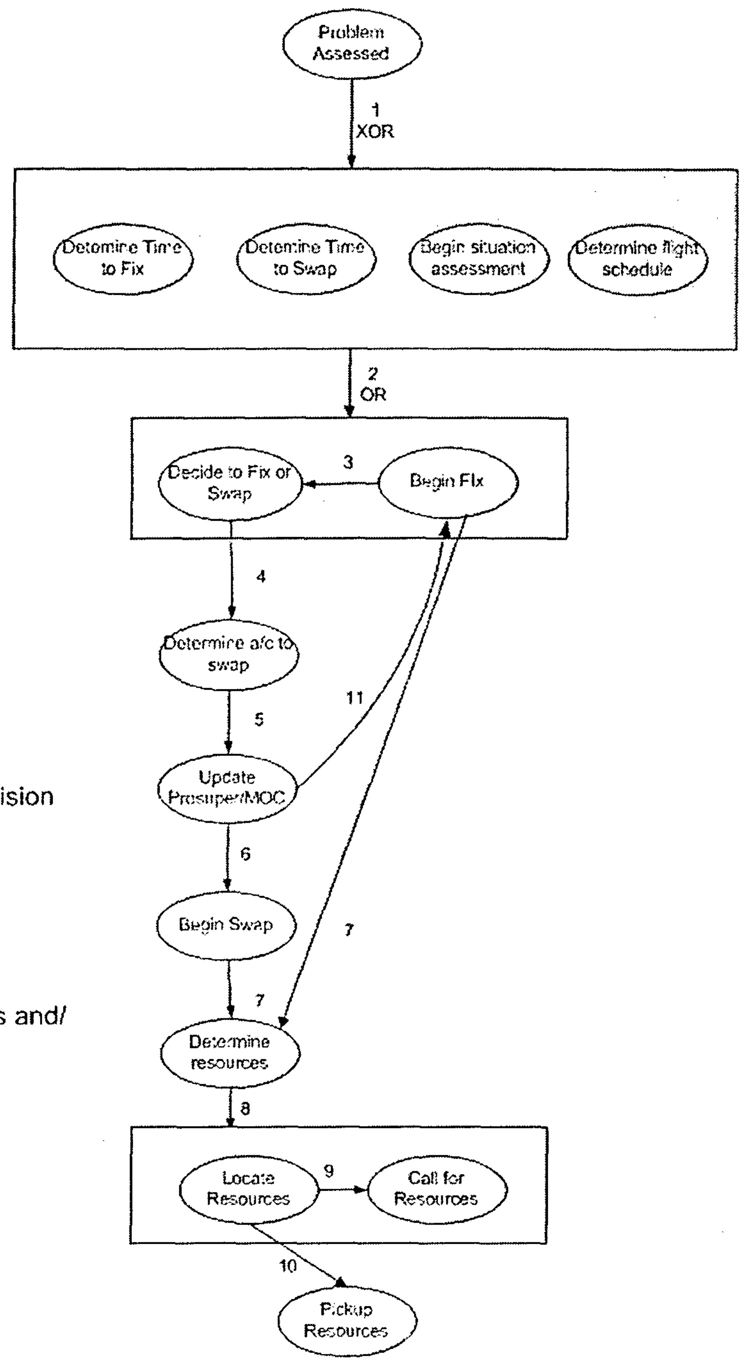
Begin Fix
a. defuel
b. flares
c. jacks
d. tow team
e. review time to site

Review
a. review how swap affects overall schedule

FIGURE 21: AIRLIFT PARTICIPANTS' PROCESS FLOW USING BASELINE

5.6.5 Validation of the Cognitive Model

One purpose of the Scientific Study was to validate the cognitive task analysis presented in Section 3.2. The Scientific Study focused on the task of assessing aircraft status and the fix/swap decision. The original cognitive task analysis OFM diagram for Assess Aircraft Status shown in Section 2.3.2 of Appendix B provides the OFM-COG analysis. The results of the verbal protocol indicate the general process described by the OFM-COG is accurate. The Scientific Study breaks down the fix/swap decision in more detail. Figures 22 is a new OFM diagram detailing the verbal protocol results based on the WhereNet and Baseline conditions (combined) from the point in the process where the problem has been accurately assessed. Table 14 is the new OFM-COG analysis. The OFM diagram and OFM-COG analysis based on verbal protocols when using SSLC2 are presented in Figure 23 and Table 15.



1. Analyze information
2. Start fix or make final fix/swap decision
3. Fix started
4. Swap chosen
5. Notify personnel
6. Execute decision
7. Resources required
8. Resources identified
9. Resources available via other units and/ or owners.
10. Resources need pickup
11. Prepare a/c for next sortie

FIGURE 22: FIX/SWAP DECISION OFM DIAGRAM FOR WHERENET AND BASELINE

Gray boxes are those that have been changed to reflect the results from the Scientific Study.

TABLE 14: "ASSESS AIRCRAFT STATUS" FUNCTION UPDATED OFM-COG ANALYSIS FOR WHERENET AND BASELINE CONDITIONS

OFM Function/Sub-function	Cognitive Agent Tasks	Input	Human Information Processing Resources	Output	Task and Environmental Demand
Assess Aircraft Status	Input select	Status sheet, Maintenance sheets, Radio, Personnel communication, weather, Visual inspection	Selective attention Perceptual sensitivity	Aircraft status code, A/C to monitor	Number of A/C to be monitored, Deployed war time environment, Time critical missions, mission priority
	Identify	Aircraft status code, A/C to monitor	Perceptual discrimination, long term memory, working memory	Identification of problems, issues, current state within maintenance processes	Expertise, Number of items to identify
	Interpret	Identification of specific problems, issues, current state within processes	Long term memory, sustained attention	Narrowing of issues	Number of problems, problem complexity
Identify Problem	Transmit	Narrowing of issues	Response precision	Request and receive problem assessment, narrow issues	Expertise, Correct problem assessment, complete assessment
Determine how to meet sortie	Compute	Problem assessed	Working memory, processing strategy, Long term memory, sustained attention	Determine time to fix, current time, aircraft schedule, specific task steps necessary.	Expertise, knowledge of tasks required, knowledge of time to complete tasks, aircraft schedules
	Decide/select	Determine time to fix, current time, aircraft schedule, specific task steps necessary.	Working memory, processing strategy, Long term memory, sustained attention	Start Fix before making swap decision	Expertise, knowledge of tasks required

OFM Function/Sub-function	Cognitive Agent Tasks	Input	Human Information Processing Resources	Output	Task and Environmental Demand
	Decide/select	Determine time to fix, current time, aircraft schedule, specific task steps necessary.	Long term memory, Processing strategy	Decision to fix or swap aircraft.	Expertise Aircraft availability, Impact on flying schedule
	Plan	Decision to fix/swap	Working memory, processing strategy	Plans for resources required to carryout fix and swap tasks.	Expertise, Number of resources and their status, location, who to call
	Search Filter	Plans for resources required to carryout fix and swap tasks.	Sustained attention, perceptual sensitivity	Locating resources needed. Filtering resource lists on computer system.	Knows what resources are required. Number to detect. (For WN, ability to detect location on computer system).
	Transmit Store	Resources located	Response precision	Transmit decision and plans to appropriate resources. Update status sheet, Update A/C status	Ability to transmit information to appropriate personnel and update recording system.
	Adapt/learn	Unique problem	Long term memory	New knowledge	Recognize unique or first experience with problem.

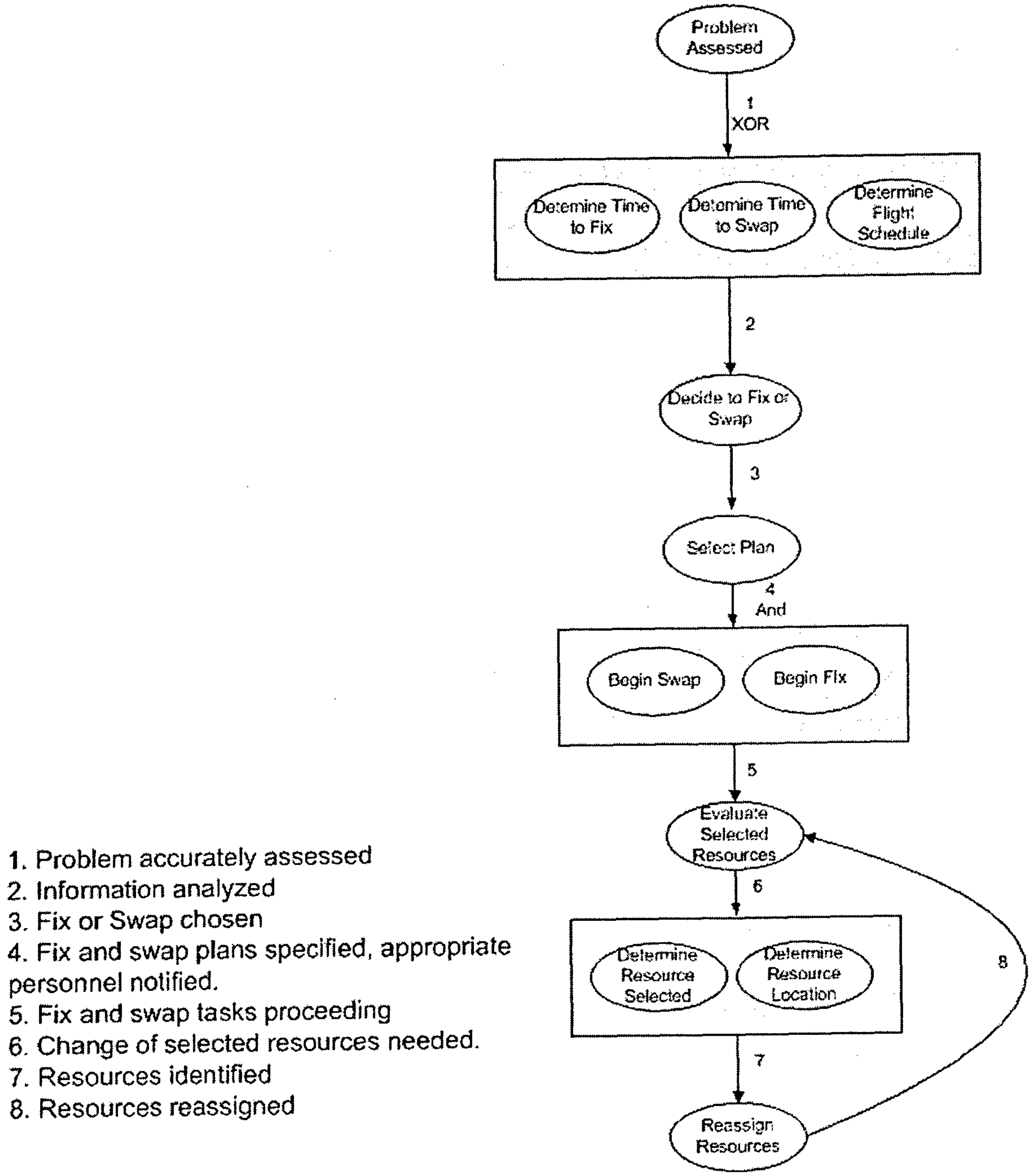


FIGURE 23: FIX/SWAP DECISION OFM DIAGRAM FOR SSLC2

TABLE 15: "ASSESS AIRCRAFT STATUS" FUNCTION UPDATED OFM-COG ANALYSIS FOR SSLC2

OFM Function/Sub-function	Cognitive Agent tasks	Input	Human Information Processing Resources	Output	Task and Environmental Demand
Assess Aircraft Status	Input select	Aircraft schedules and status from computer system.	Selective attention, Perceptual sensitivity	Knowledge of aircraft status codes, maintenance activities, A/C schedules.	Number of A/C to be monitored. Deployed war time environment, Time critical missions, mission priority. Ability to locate and visualize information on computer system Number of items to identify.
Identify Problem	Detect	Problem presented and detailed on computer system.	Perceptual discrimination, long term memory, working memory	Detect specific problems. Problem assessed.	Expertise, Ability to locate and visualize information on computer system, Number of items to identify. Location of information within computer system.
Determine how to meet sortie	Plan	Problem assessed	Working memory, Processing strategies	Review time to fix, current time, aircraft schedule, specific task steps necessary.	Ability to locate and visualize information on computer system.
	Decide/select	Review time to fix, current time, aircraft schedule, specific task steps necessary.	Long term memory, processing strategy,	Decision to fix or swap aircraft.	Ability to locate and visualize information on computer system.
	Plan	Decision to fix/swap	Working memory, processing strategy	Review recommended plan including recommended resources.	Ability to locate and visualize information on computer system, knowledge of personnel qualifications and abilities
	Plan	Plan selected	Working memory, processing strategy	Evaluate and update recommended resources.	Ability to locate and visualize information on computer system, knowledge of personnel qualifications and abilities.

OFM Function/Sub-function	Cognitive Agent tasks	Input	Human Information Processing Resources	Output	Task and Environmental Demand
	Adapt/learn	Unique problem	Long term memory	New knowledge	Recognize unique or first experience with problem.

Because SSLC2 provides fix and swap task information, assigns the personnel and equipment and automatically notifies personnel to begin the fix and swap tasks, many Expeditor subtasks (determine aircraft to swap, notifying personnel, determining resources) are eliminated under the SSLC2 condition. During the fix/swap decision process participants did not spend time trying to reassign resources to the problem once SSLC2 made selections. Several participants indicated they were likely to make such changes based on their knowledge of personnel and their skills.

Incorporating a computer based technology system like SSLC2 into the maintenance process changes how the tasks are carried out and the type of cognitive processing required by the Expeditor. Time is spent detecting and reviewing information presented by the system rather than searching for information from a wide variety of sources and mentally integrating the task steps and times.

A very in-depth task analysis specifying each screen and computer input when using SSLC2 was not conducted because the system design was not being tested, nor is this specific design being recommended. While SSLC2 was able to provide additional information, the interface required too many steps to carryout the tasks. However, the results show there can be reduced need for interruptive radio communication and mental integration and many participants were open to the use of such a technology.

5.7 SUMMARY OF RESULTS AND DISCUSSION

The Expeditors primary goal is to facilitate maintenance so sorties can be met. The study focused on the task of assessing aircraft status and the fix/swap decision. As stated in the Section 4.0 the objectives of the Scientific Study were to:

1) Validate the cognitive model developed from data collection interviews through verbal protocol (source) techniques and to determine what information is most useful to help Expeditors make flightline decisions.

2) Evaluate user performance and opinions on enhanced data streams.

5.7.1 Summary of Objective 1: Validating the Cognitive Model

The results of the study indicate that the cognitive representations presented in Section 3 were accurate. The OFM diagrams in Section 2.3.2 of Appendix B show that

the Expeditor reviews a variety of information input which leads to problem identification. Once the problem is identified, the Expeditor has the maintenance problem assessed by a specialist. The study took place from the point where the assessment had been made.

Upon assessment the next task is to determine how the sortie can be met, by fixing, swapping or using a spare aircraft. Using a spare aircraft is not a swap if it is on the flying schedule. If it is not on the schedule it is considered a swap and a deviation to the flying schedule. Resources needed are determined and located and the Expeditor continues to monitor maintenance progress to continue toward the goal of meeting the flying schedule. The results show that this is the general process participants took during all three conditions so the basic model is accurate. Additionally, more specific information was provided showing that strategies differed among participants and between aircraft type (airlift vs fighter). Once the problem is identified and assessed by a Specialist, the Expeditor quickly makes the fix/swap decision focusing primarily on the time to fix and the flight schedule. The updated OFM diagram (Figure 23) breaks down the process in more detail as does the OFM-COG table (Table 14). However, different participants had different strategies, with some participants reviewing the situation more in-depth and some beginning tasks for the fix before making a fix/swap decision. The most interesting finding is that when the SSLC2 decision support tool is introduced, the participants do change their process. In this case, participants no longer needed to determine the specific tasks and how long it would take overall to fix the aircraft, reducing the need for mental calculations and the need to call a variety of sources for information. Participants followed the SSLC2 recommendation to fix or swap and which aircraft to swap with. Use of this system in a deployed setting when they might be more familiar with resources may result in more time spent making changes to the fix tasks, times, and resources assigned. Or they may just trust the recommendation. During this simulation they were not familiar with all available resources and personnel so they took the information at face value.

Another validation of the model is that when using the SSLC2 simulation participants commented on pieces of information that were not available in the SSLC2 simulation system, personnel skill level and certifications. They did not specifically search for the

information, but they stated that it would be beneficial, especially if they did not know everyone on the flightline. The fact that they did not request additional information indicated the initial simulation system was able to capture important information needed for the decision process.

5.7.2 Summary of Objective 2: User Opinions On Enhanced Data Streams

User opinions on the enhanced data streams were elicited through questionnaires at the end of each condition and at the end of the study. Both the WhereNet and SSLC2 condition have enhanced data streams showing resource location. SSLC2 has additional data including aircraft status and location, aircraft maintenance schedules, daily flying schedules, personnel and equipment resources and their locations, tasks necessary to fix the broken aircraft, tasks necessary to swap an aircraft, time to complete fix tasks, time to get resources to the fix site, resource types necessary to complete tasks, specific resources assigned to tasks, and a recommendation to fix or swap an aircraft.

The ranking data indicated that participants preferred SSLC2 to both WhereNet and Baseline. However, they preferred Baseline to WhereNet. These results show that participants prefer advanced data streams if the information is presented in a way that helps with their tasks. While WhereNet provided enhanced data, many participants felt that WhereNet did not do a good job of presenting the information in a usable way, resulting in information overload.

When participants rated 15 statements related to the use of the technology, their overall ratings for SSLC2 were higher than both WhereNet and Baseline. WhereNet ratings were higher than Baseline. The average rating for Baseline is still high ($X = 5.0$) indicating on average participants slightly agreed with the statements overall.

Several statements on the post condition questionnaire and post test ranking questionnaire were related to monitoring the status of resources, locating both equipment and personnel resources, and availability of both equipment and personnel. In general, the results showed users preferred SSLC2 to both WhereNet and Baseline. They rated both SSLC2 and WhereNet better than the Baseline for these resource activities.

5.8 EXPERIMENTER OBSERVATIONS

During the study experimenters made notes about their observations. These observations along with suggestions and feedback provided by the participants are summarized below.

5.8.1 SSLC2 Functionality

Participants made positive comments about the ability to get an overview of the flightline, both geographically and as a schedule, and liked being able to dig deeper into aircraft problems and tasks to be worked. Participants frequently worked between the top level and lower level views, specifically to see how the aircraft problems affected the overall flightline schedule. Participants varied in how frequently they moved between the views depending on their current maintenance role. Those concerned with solving aircraft problems tended to work within the problem schedule or geographic views while others, such as ProSupers, looked for potential schedule impacts.

The Scientific Study focused on one aircraft problem needing attention; however each scenario had another aircraft that was NMC as well. The specific task information to work that problem was not provided in the scenario. Expeditors and ProSupers expect to multitask and need to respond to more than one problem at a time. Frequently the participants wanted to work all aircraft problems to see how they affected the flying schedule and spare availability. Participants suggested that a future system give them the ability to multitask and give information about every aircraft to help with decision making. Multiple problems will be investigated in the next Spiral.

SSLC2 also broke each problem into a series of tasks to be completed. Each task listed associated equipment and personnel resources with their time to site and time to fix. Participants liked seeing the list of tasks and said they would use this feature on the real flightline where they know their resources. Participants said they would like the ability to create or modify the tasks needed to fix problems. The entire listing of tasks and resources was overwhelming to some participants so they suggested minimizing tasks once they are completed to avoid scrolling through tasks already accomplished. Participants sometimes referred to the wrong task when trying to change a resource.

The scenarios identified flightline equipment and personnel resource problems needing attention. Participants were asked to identify a new piece of equipment or person to replace the problem resource. Within the SSLC2 condition participants needed to work through a series of screens to find and replace a resource. Adding comparisons generally required seven to eight steps. Many participants commented that the capability of changing resources was necessary however the current functionality has too many steps. They said the information provided such as the time to site, resource location and names were helpful. Suggestions included reallocating new resources from the problem geographic view or original task lists. Some participants suggested a click and point interface rather than dialog boxes and pull downs.

Additional items and comments highlighting positive aspects of SSLC2 functionality included the ability to zoom in and out within the geographical views. Some participants used this feature to view all resources on the entire flightline while others zoomed into the problem aircraft and resources associated with the fix. This functionality allowed participants to tailor views based on their individual needs.

Suggestions for functionality enhancements included incorporating the positive aspects of WhereNet, particularly the ability to filter by resource types or finding specific resources through a drop down menu or wildcard selection. The filter ability would allow users to see only the details necessary and eliminate the problem of too much information.

Participants had numerous concerns with hardware functionality. Many participants said the current version of SSLC2 was optimal for someone at a desk and not in a truck, the typical place of an Expeditor. Participants said any system would have to be portable, ruggedized and wireless.

5.8.2 Validation and Alerts

Expeditors currently use two-way communication using radios. When they make a request they are given a confirmation that the information has been received, and continue to receive information updates. The simulation did not include the two-way communication. Many participants stated that they would expect validation from the flightline resources that messages were received from SSLC2. The only feedback in the

simulation was movement of resources, however, they did not watch for the movement as they are busy moving to other tasks. Possible validation considerations include communicating flying schedule and resource changes to those on the flightline, monitoring when tasks are complete and sending resources to site.

Participants were also concerned maintainers would not monitor the computer screen for all changes so some other alert or validation is necessary to know they received the changes.

5.8.3 Tagging Personnel

Participants thought the ability to see personnel location could be extremely important on the flightline. Many participants indicated that the biggest difficulty they have, particularly as ProSupers and Expeditors, is finding people. Many indicated that a large amount of time is wasted searching for personnel. They indicated that tagging identifications could be especially useful when you needed someone with specific certifications quickly. One challenge to tagging personnel resources is that the Expeditor and ProSuper are not always the direct supervisor of all flightline personnel. They do not necessarily know what task a Specialist has been assigned. Other challenges are social including the concern with privacy as well as issues of trust. Many bases, particularly Guard and Reserve Units, have unions and the civilian culture would be more resistant to RFID tagging. However, during deployed missions this is not an issue and may be extremely beneficial during wartime operations.

5.8.4 Sensors and Additional RFID Considerations:

The SSLC2 system provided a simulation of RFID/RTLS technology to track personnel and equipment location. Participants were asked what additional information should be collected through sensors that would impact flightline decisions. They indicated that information such as base supplies on the Quick Reference List, equipment status (FMC/NMC), fuel level, oil level, liquid oxygen level, and usage status (in use or not in use) would be useful. All of these items were mentioned numerous times at all field test locations. Participants said this information could aid in making cannibalization and fix/swap decisions. RFID/RTLS and sensor information could help participants prioritize tasks and resources.

Tagging every resource on a flightline could be overwhelming. Participants verbalized that WhereNet had too much information at times because everything was tagged and the most critical information was not readily accessible. Participants at Ft. Wayne suggested tagging Low Density/High Demand (LD/HD) items, such as mules and jacks. Participants indicated there are resources either in supply or frequently used or borrowed that would be more important to tag.

6 Recommendations

Spiral One of the SSLC2 program was successful in providing input toward requirements specifications. The Scientific Study helped to determine concepts for SSLC2, showed that enhanced data streams can help support flightline decisions, and provided information on important data elements to include in a system. This section first outlines some recommendations based on the output of all Spiral One phases. The initial requirements are then briefly presented. Future research questions related to the concepts of SSLC2 are then discussed followed by plans for Spirals Two and Three.

6.1 SPECIFIC RECOMMENDATIONS

The research conducted to date provides input for recommendations for SSLC2 concepts. Recommendations are discussed below.

6.1.1 Sensor Information

Results of this effort have shown that the incorporation of real time sensing technologies can improve flightline logistics support. For this spiral RFID/RTLS was simulated to show resource (equipment and personnel) location information. This information along with other decision support information was presented to Expeditors and the overall result was positive. The results also pointed out additional information used in decision making that could be sensed and integrated and are listed below.

- Supplies on the quick reference list;
- Equipment Status (broken, in use, not in use);
- Equipment fuel level;
- Liquid oxygen level;
- Temperature;

- Battery level; and
- Oil levels.

Sensing supplies on the quick reference list (supplies on base only) was an important element to most participants. The ability to quickly determine if those supplies were available would shorten the decision process. Additional sensed information should be evaluated to determine how and when they would be used so that it can be integrated into the system effectively. Efficient use of sensors and integration of the information is critical and the potential for information overload is very high. It is recommended that information related to LD/HD items is sensed.

6.1.2 Portability

As mentioned previously, the SSLC2 system would have to be hand held or highly portable. Most participants indicated the laptop system would not be feasible for an Expeditor. It is highly recommended a handheld portable device be used for SSLC2. The concept of incorporating both the visualized information and verbal communication in one unit should be explored. Perhaps Voice Over Information Protocol (VOIP) could be incorporated. It is highly unlikely that SSLC2 would eliminate the need for some verbal communication between team members on the flightline. The concept is to create one system the Expeditor believes he can not do without.

6.1.3 Direct Manipulation Interface

SSLC2 should have a direct manipulation interface to include features such as point and click interactive visualizations and a drag and drop interface. These types of features minimize the information displayed to just the pertinent information required, and eliminated unnecessary information. They allow the user to tailor the interface to their preferences and decision support needs. These also minimize the number of steps and screens required to reach the required information.

6.1.4 Tailored to Different User Types

As the Scientific Study results indicated, participants made their decisions in a number of different ways. Some participants were more interested in the current problem while others wanted to know additional information regarding every aircraft on the flightline. Some participants wanted to see the impact of their decisions on the overall

flying schedule while others were interested in information regarding resource location. The diversity of interests and information needed to make decisions necessitates a user interface design tailored to different user types.

SSLC2 must present the right information at the right time for the user to make an actionable decision and allow the user to filter out all the unnecessary information. Each user wants the ability to tailor their screen and views to their specific job requirements.

6.1.5 Information Playback

The current environment is so manually labor intensive, the SSLC2 experiment gave many of the participants a first opportunity to explore automated tracking of many of their tasks and decisions. Using these concepts, participants expressed interest in being able to review what occurred over a previous time period and study the decisions and impacts for trends analysis and lessons learned.

6.1.6 Validation and Alerts

As mentioned earlier, Expeditors currently use two-way communication through radios. Participants expressed the necessity to have any potential system give them feedback that a message was received and an action or task had started. Considerations include communicating flying schedule and resource changes to those on the flightline, monitoring when tasks are complete and sending resources to site.

Participants also liked the idea of visualizing the tasks required to complete a job and monitoring the progress of those tasks. Suggestions include sending notices to resources to work the tasks and sending notices if task completion times are in jeopardy of impacting the schedule.

6.1.7 Fix/Swap Decision Recommendations

SSLC2 should have more complex algorithms for fix/swap decision (i.e. not just based on fix time). SSLC2 should investigate additional input variables for the fix/swap recommendation. Expeditors do not work just one fix/swap decision or one aircraft at a time but are multi-tasking many problems across the flightline. Expeditors have many different parameters in their decision strategy and SSLC2 should incorporate these complex variables and strategies.

6.1.8 Performance Feedback

SSLC2 should have the ability to include reports on performance metrics. This will provide the users feedback on how their decisions affect performance metrics over time. The feedback to the user shows the system is providing useful support. This feedback can be accomplished in two ways. Two-way communication is the most important form of feedback expressed by the participants. They need validation their messages were received and acted upon. The second form of performance feedback supports metric improvements. With the ability to playback past actions quickly they can analyze impacts to their performance metrics and determine how actions impacted those metrics. In essence, the can drill down to the cause and effect of changes to performance metrics using the playback capabilities and make future strategy decisions based on those results.

6.2 REQUIREMENTS

An output of this research is to provide requirements that can be transitioned into an existing legacy system. Requirement building has taken place throughout the entire program. They were defined through the literature search, data collection, and field test.

6.3 RESEARCH QUESTIONS

The Spiral One effort identified SSLC2 research areas for the future spirals as well as future research projects beyond the current SSLC2 contract scope. This section presents these research questions.

The main research issue for the next SSLC2 Spiral is how to integrate information from enhanced data streams when focusing on the multiple tasks and problems that occur on the flightline. Spiral One focused on one aircraft problem, however, SSLC2 must be able to integrate information in a complex environment in which multiple problems and tasks are occurring. This research focus supports one of General Martin's (AFMC/CC) main focus areas as stated in October 2004, "We need to visualize our environment and transfer all this information into actionable decisions."

Research should address various ways the information is integrated and presented, and how various user types would interact with the system. Research questions include which information can be sensed? How should the information be fused so as not to

overwhelm the user? Who should get what information, when, and how should it be presented? How can the necessary information be provided to the user in a timely manner, on a small portable system that allows the user to make actionable decisions and maintain situation awareness? Depending on the decisions to be made, different visualization techniques may be better for portraying specific information. The goal is to ensure that users are not overwhelmed with information they do not need.

The ability to query the information should be studied, including investigation of the use of computer agents that can be tasked to search and provide appropriate information. Computer agents that adapt and learn user needs and preferences could be incorporated in the future. External research in this area is progressing for searching and presenting information from large web-based information sources.

Decision support is directly linked to the user's ability to maintain situational awareness (SA), both local SA (specific task) and global SA (entire situation). Expeditors need to maintain global SA, but also focus on specific tasks. How the system can help the user maintain global SA when they often must drill down to specific problems must be considered.

Another research focus would be evaluating the use of a hybrid decision support system using an interactive model based approach versus a traditional decision support tool that is based only on information fusion and presentation. With this approach, interactive algorithms, for example sortie scheduling algorithms, can be implemented to include real time human interaction.

This hybrid decision support system could include algorithms that determine the assignment of resources for the week while allowing the Expeditor or ProSuper to change those assignments based on information not available within the algorithm. These assignment changes are often based on supervisors' personal knowledge of capabilities or their desire to balance training requirements and match skill sets, etc. Research could be conducted to investigate whether this approach would help the supervisor expedite decisions that are currently made using manual information related to personnel certifications, skill level, training records, appointments, etc.

Another research issue is how collaboration among multiple decision makers on the flightline affects the decision making process and how to best support collaborative decision making. If flightline personnel (MOC, ProSuper, Expeditors, Crew Chiefs, specialists, scheduler, etc) were provided with collaboration tool how would their decisions strategies change? How would the process change? Would performance metrics be positively impacted?

6.4 SPIRAL TWO AND THREE PLANS

The vision of SSLC2 is to provide decision quality information from multiple data streams including real time location and status data for monitoring capabilities, as well as algorithms to equate resource availability to operational capability. Decision-makers will be provided insight to the operational impact of their decisions. The SSLC2 effort is researching the fusion of technology with information to provide decision support and situational awareness aimed at demonstrating the capability for improved decision making that can affect operational capability.

Spiral One was scoped solely at wing-level personnel focusing on one primary decision, the fix/swap decision of one aircraft. The goal was to test the proof of concept of the fusion of RFID/RTLS technology to provide decision support and situational awareness. The Scientific Study showed that the user preferred the integrated decision support tool over RFID technology that does not integrate information based on the user tasks.

Spiral Two is an instantiation of the SSLC2 concept using the VSLRC contract modification to SSLC2, providing the Air Force Space Command (AFSPC) and Space and Missile Systems Center (SMC) an actual implementation of the SSLC2 concepts. Rather than using RFID/RTLS technology, VSLRC fuses data from numerous AFSPC sources to provide logistics status of space ground assets to determine their operational capability. Spiral Two is scoped at the theater level personnel focusing on the Space users, providing situational awareness, and making logistics support decisions to keep operational, communication, and equipment status as high as possible. Spiral Two research will focus on assessing user opinions of the visualizations and improvements to

situational awareness provided by this new capability. The previous system was manual and non-standard across the space systems.

Spiral Three will expand on the work accomplished in Spiral One focusing on how enhanced data streams impact complex multiple decisions. Collaboration among users and integration of information is a key part of this TAD. Multiple users will have access to the same information. The users will be able to work multiple problems on multiple aircraft at the same time. The technology concept will be expanded beyond RFID/RTLS location information to include additional sensor information. Research questions include: How does the visualization techniques affect the decision making process? Does data fusion improve the timeliness of information extraction and decision making? How is SA affected? A key component of the research will be SA, including the evaluation of both global (entire flightline) and local (current specific problem) SA.

7 Conclusion

SSLC2 is investigating technologies and techniques to autonomously collect and fuse critical data to provide decision quality information and effectively present information to support cognitive tasks performed by logistics and operations decision-makers. Today's logistics and operational environment has little cross echelon situational awareness. Data capture and decision analysis are largely manual processes. Many of the current systems are standalone and do not share data. Personnel are often challenged when trying to locate the resources they need to perform their job. Personnel need a means to identify the impact of their logistics actions on operational capability. SSLC2 provides decision quality information fused from enhanced data streams such as RFID/RTLS technologies, smart sensors, computing technologies, and information networks.

SSLC2 Spiral One focused on developing requirement specifications for using real time sensing information as well as legacy system data to help flightline personnel make decisions and understand how their decisions are affecting flightline operations. A Scientific Study was designed and conducted to study the impacts of enhanced data streams provided by RFID/RTLS technology and fused data from legacy systems and potential future automated capabilities. The Scientific Study objectives were to:

1) Validate the cognitive model developed from data collection interviews through verbal protocol (source) techniques and to determine what information is most useful to help Expeditors make flightline decisions.

2) Evaluate user performance and opinions on enhanced data streams.

The Scientific Study compared three conditions. The SSLC2 condition integrated RFID/RTLS technology with flightline information for improved decision making. The off-the-shelf technology condition called WhereNet provided location of resources but did not integrate the information with the Expeditor's work and decision process. The Baseline condition was included as a control condition, allowing for comparison of the SSLC2 approach to current practice and enabling validation of the cognitive model.

The Scientific Study focused on the fix or swap decision construct identified in the data collection and cognitive task analysis processes. The verbal protocol technique was used to collect data related to the types of information and processes the Expeditors use to make the fix/swap decision. Participants were also asked to provide their opinions of the three conditions. The hypothesis was that participants would prefer the SSLC2 approach compared to the WhereNet off-the-shelf RFID/RTLS technology system. Because participants are so familiar with current practice and often resistant to change, it was hypothesized that there would be no difference in preferences between the SSLC2 approach and the Baseline current practice approach.

Results showed that the hypothesis that participants would prefer the SSLC2 approach compared to the WhereNet and Baseline was supported. Participants gave higher preference rankings to SSLC2 over both WhereNet and Baseline. WhereNet was ranked lowest, but it was not statistically different from Baseline. When participants rated their agreement with a variety of task statements there were no differences between SSLC2 and WhereNet. User commented that interaction with WhereNet was somewhat difficult. The results also showed the cognitive model, developed after initial interviews, was accurate. The Scientific Study verbal protocol results provided more detailed decision strategies.

The results also indicate that SSLC2 must consider how enhanced data streams (such as location of resources) can be integrated with existing information to support user tasks

and decisions within the context of their work. Location information as a stand alone system (WhereNet) was not preferred.

Participant feedback indicated that they supported the concept of enhanced data streams using RFID/RTLS technology and provided feedback and suggestions for additional information that can be sensed.

The next step for SSLC2 is to evaluate the integration of information from enhanced data streams when focusing on the multiple tasks and problems that occur on the flightline.

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Appendix A
SSLC2 Acronyms

Acronym	**Definition**
A/C	Aircraft
AB	After Burner
ACS	Agile Combat Support
AFB	Air Force Base
AFFOR	Air Force Forces
AFI	Air Force Instruction
AFMC	Air Force Materiel Command
AFRC	Air Force Reserve Command
AFRES	Headquarters Air Force Reserve
AFRL	Air Force Research Laboratory
AFRL/HEAL	Air Force Research Laboratory Warfighter Readiness Research Division
AFRL/HECV	Air Force Research Laboratory Information Visualization
AFSC	Air Force Specialty Code
AFSOC	Air Force Special Operations Command
AFTO	Air Force Technical Order
AGE	Aerospace Ground Equipment
AIT	Automatic Information Technologies
ALS	Autonomic Logistics System
AMU	Aircraft Maintenance Unit
ANG	Air National Guard
ANOVA	Analysis of Variance
AOC	Air and Space Operations Center
API	Application Programming Interface
AR	Aerospace Repair
ATD	Advanced Technology Demonstration
ATO	Air Tasking Order
ATOC	Air Terminal Operations Center
C2	Operations Command and Control

Acronym	Definition
CAMS	Core Automated Maintenance System
CAP	Combat Air Patrol
CONUS	Continental United States
DSRC	Dedicated Short Range Communication
E&E	Environmental & Electrics
EMOC	Enhanced Maintenance Operations Center
ETIC	Estimated Time to Completion
FMC	Fully Mission Capable
FOD	Foreign Object Damage
FSE	Flying Schedule Effectiveness
GO81	Air Mobility Command CAMS
GUI	Graphical User Interface
HQ	Headquarters
HTTP	HyperText Transport Protocol
ICT	Integrated Combat Turns
IMIS	Integrated Maintenance Information Systems
IRA	Interface Requirements Agreements
ASO	Inspection Operations
ITV	In-Transit Visibility
JDBC	Java Database Connectivity
JOAP	Joint Oil Analysis Program
JQS	Job Qualification Standard
KPP	Key Performance Parameters
LCOM	Logistics Composite Model
LD/HD	Low Density/High Demand
LG	Logistics Group
LOCIS	Logistics Command and Control Information Support
MAJCOM	Major Command
MC	Mission Capable
MEDAF	Mediterranean Air Force

Acronym	Definition
MICAP	Mission Capability
MOC	Maintenance Operations Center
NMC	Non-Mission Capable
OFM	Operator Function Model
OFM-COG	Operator Function Models supplemented with COGnitive Information
OG	Operations Group
PMC	Partially Mission Capable
ProSuper	Production Supervisor
RAM	Random Access Memory
RF	Radio Frequency
RFID	Radio Frequency Identification
RTLS	Real Time Locating System
SA	Situational Awareness
SME	Subject Matter Expert
SSLC2	Smart Systems for Logistics Command and Control
STABOS	Stability Operations
TAD	Technology Availability Date
TO	Technical Orders
TRT	Take-Off Rated Thrust
USMEDCOM	United States Mediterranean Command
VOIP	Voice over Information Protocol
VSLRC	Virtual Space Logistics Readiness Center

Appendix B
Data Collection

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1 Introduction

Appendix B, Data Collection, contains background information detailing the data collection and data analysis processes highlighted in the SSLC2 Spiral One Final Report. This document follows the main document giving additional details about the Spiral One Methods and Approach including systems analysis, data collection, storyboard development, and knowledge representations. The Results and Discussion section contain the original data rankings and frequencies and information obtained through verbal protocol analysis.

2 Spiral One Methods and Approach

2.1 SYSTEMS ANALYSIS AND DATA COLLECTION

A variety of Data Collection Strategies were used throughout the Spiral One Scientific Study design and development to obtain user feedback on decision making. Data collection revealed that some potential users make a variety decisions and, therefore, multiple techniques to gather data were required.

Through process interviews, cognitive interviews, and shadowing the team collected data to help understand the decision making process and daily decisions that potential users make. This data was also used to refine requirements for the Scientific Study. Figure 1 shows the different data collection methods used at each location during early data collection efforts.

Data Collection Method by Location

	Hurlburt AFB	WPAFB HQ AFMC	WPAFB	Springfield OANG	Luke AFB
MOC			Process	Process	Process
Mx (Expediters, Pro Supers)			Process	Process	Shadowed, Process, Cognitive Interviews
AGE (Dispatchers, Supervisors, Drivers)	Process		Process, Cognitive Interviews	Process Cognitive Interviews	Shadowed, Process, Cognitive Questions
Fuel (Drivers, Supervisors)	Process				Shadowed, Process, Cognitive Questions
Deployment Managers		Informal team interview	Process, Cognitive Interviews		Process, Cognitive Interviews

FIGURE 1: DATA COLLECTION METHOD BY LOCATION

Data collection revealed a number of user problems. The problems in Table 1 are common flightline problems addressed by flightline maintainers.

TABLE 1: USER PROBLEMS AND ISSUES

User Problem	Issues
Tracking and allocating borrowed equipment across Combat AGE Teams (CATS).	o Which CAT has a surplus of a particular piece of equipment that can be borrowed? o Where is the equipment located? o What is the operational status of the equipment? o What is the availability of the equipment? o When should the borrowed equipment be returned?
Identify the "right" equipment for a particular maintenance task.	o What type of equipment is needed for the maintenance task and what is the estimated duration for the task? o Where is the equipment located? o What is the operational status of the equipment? o What is the availability of the equipment?
Identify which equipment technicians are finished using and where it should go.	o What visual cues indicate that a technician is finished using a piece of equipment? o Where is the equipment required next?
Identify the shortfalls in available equipment due to inspections/preventative	o What equipment needs to be pulled? o What equipment is going to replace it and can it be used until the pulled equipment is available?

User Problem	Issues
maintenance tasks.	
Identify the equipment to be brought in for inspections/preventive maintenance.	o What equipment is overdue or coming due? o What inspections can be supported by available personnel? o Will equipment maintenance have a negative impact on the flying schedule or aircraft schedule maintenance?
Equipment is not delivered in a timely manner after call ins due to lack of prioritization.	o Prioritization is based upon multiple disparate factors (time of request, flying schedule, and identifying the "right" equipment). o What is the average delivery time? o Is there enough equipment available or will it need to be borrowed?
Identify the "right" equipment for a deployment.	o What type of equipment is needed for the deployment? o What equipment is the healthiest (up to date on their inspections)? o Where is the equipment located?

Initial data collection also highlighted critical sortie production resources that would provide value if tagged with RFID/RTLS capabilities. All of these resources are low density, high demand assets. Many of these items are either specialized or shared between units according to Luke AFB interviews. These resources include:

- Mules
- Dash 60s
- Nitrogen Carts
- Oxygen Carts
- Coleman Towbars
- Stands
- Jacks

The table below (Table 2) was created to depict how different roles within each data collection site assumed different functional/decision making responsibility. The left side is representative of three different functions (transportation, dispatch, and controller) as use case actors within the September 2004 SSLC2 use cases. Each role was aligned with a function in relation to that actor in the use cases. The columns then identify the specific site role who performs those functions.

TABLE 2: USE CASE ACTOR ROLES

	Luke AFB				
Use Case Actor	CAT Driver	CAT Lead	AGE Expeditor	AGE Pro Super	AGE Chief
AGE Transport Function	X				
AGE Dispatch Function	X		X		
AGE Control Function		X		X	X

	445th			
Use Case Actor	AGE Driver	AGE Dispatcher	AGE Pro Super	AGE Chief
AGE Transport Function	X			
AGE Dispatch Function		X		
AGE Control Function			X	X

	Springfield			
Use Case Actor	AGE Driver	AGE Dispatcher	AGE Pro Super	AGE Chief
AGE Transport Function	X			
AGE Dispatch Function		X		
AGE Control Function			X	X

Table 3 represents data collected through site visits related to the subject data required to feed Smart Systems. The left sides of each site table show the use case actor which represents the respective system. The columns along the top show the actual physical system that will feed that respective data to Smart Systems. The systems differ from site to site and sometimes are merely a spreadsheet or not even existent.

TABLE 3: USE CASE SYSTEM ACTORS

	445th WPAFB				
Use Case System Actor	GO81	CAMS	Local Excel Spreadsheets	Local C2 System	Non-Existant Information System
Maintenance Repository	X		X		
Smart Sensors (RFID)					X
SSLC2 Data Store					X
Technical Data Repository					X
MOC Status Repository					X

	Luke AFB				
Use Case System Actor	GO81	CAMS	Local Excel Spreadsheets	Local C2 System	Non-Existant Information System
Maintenance Repository		X	X		
Smart Sensors (RFID)					X
SSLC2 Data Store					X
Technical Data Repository					X
MOC Status Repository				X (ASB*)	

	Springfield ANG, OH				
Use Case System Actor	GO81	CAMS	Local Excel Spreadsheets	Local C2 System	Non-Existant Information System
Maintenance Repository		X	X		
Smart Sensors (RFID)					X
SSLC2 Data Store					X
Technical Data Repository					X
MOC Status Repository					X

* ASB - Aircraft Status Board: Local application tracking sortie generation information

** C2DB - Command and Control Database: Local MSAccess database tracking sortie generation information

2.2 STORYBOARD DEVELOPMENT

Leveraging information captured during data collection and knowledge representation stages, a series of concepts and storyboards were created and used as input into the

Graphical User Interface (GUI) design as well as the software use cases for development of the simulation test system. Figures 2, 3, and 4 are some of the preliminary screens designs created from an equipment manager work perspective.

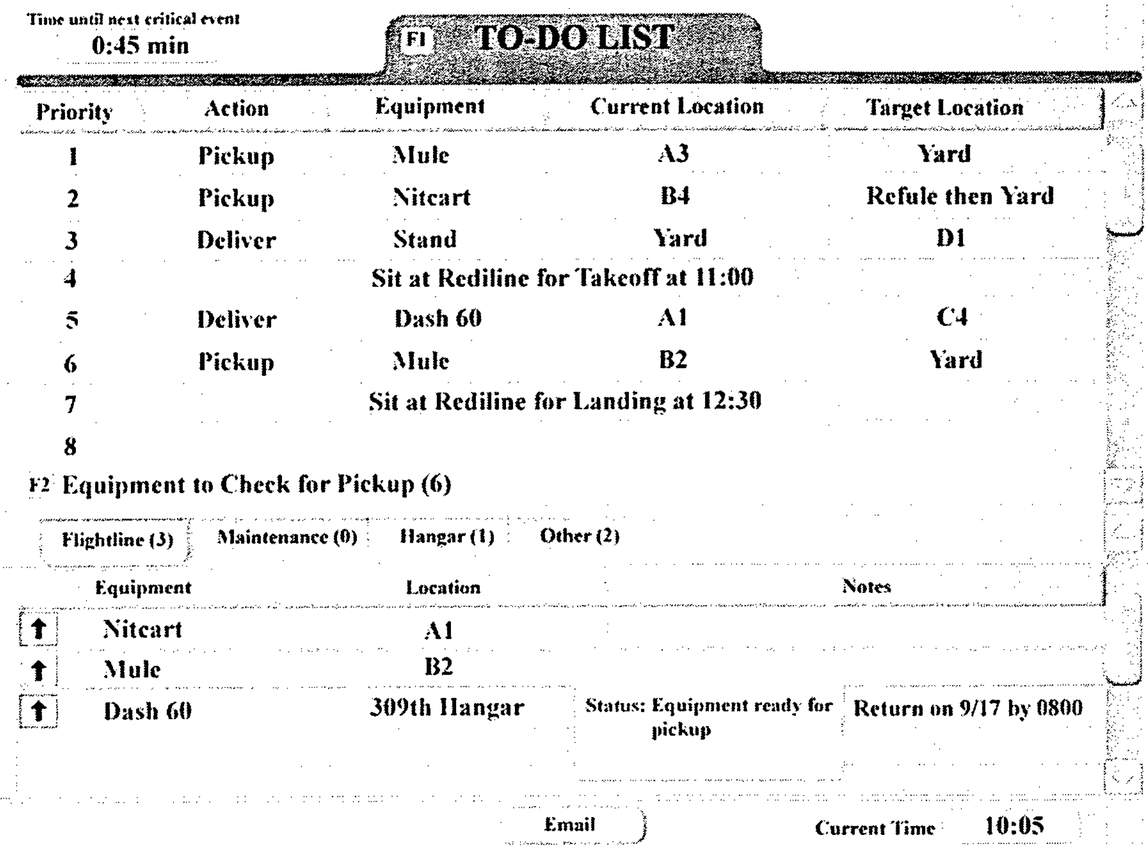


FIGURE 2: SMART SYSTEMS INITIAL TO-DO DESIGN

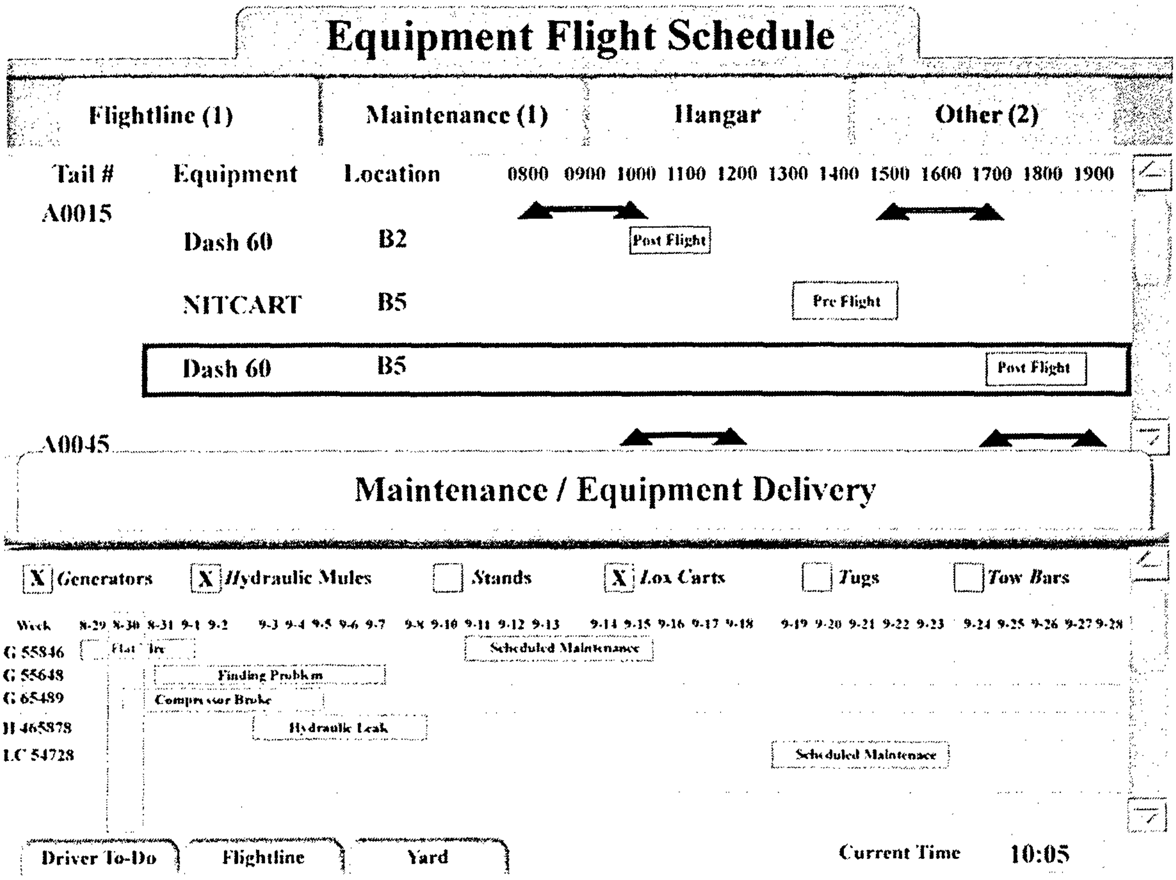


FIGURE 3: SMART SYSTEMS INITIAL EQUIPMENT AND DELIVERY SCHEDULE

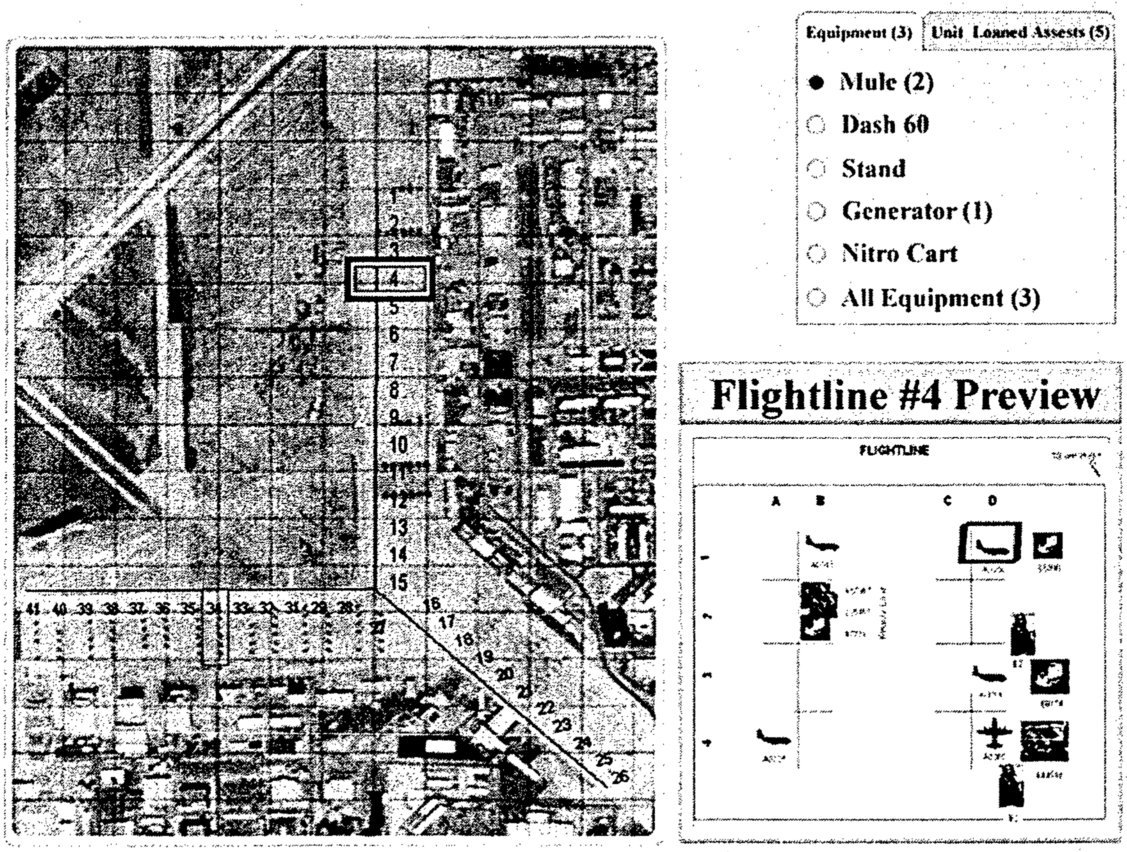


FIGURE 4: SMART SYSTEMS INITIAL OVERVIEW DESIGN

2.3 KNOWLEDGE REPRESENTATIONS

2.3.1 Hierarchical Task Analysis

The hierarchical task analysis diagrams (Figures 5-10) illustrate the Expeditor's tasks at a very high level.

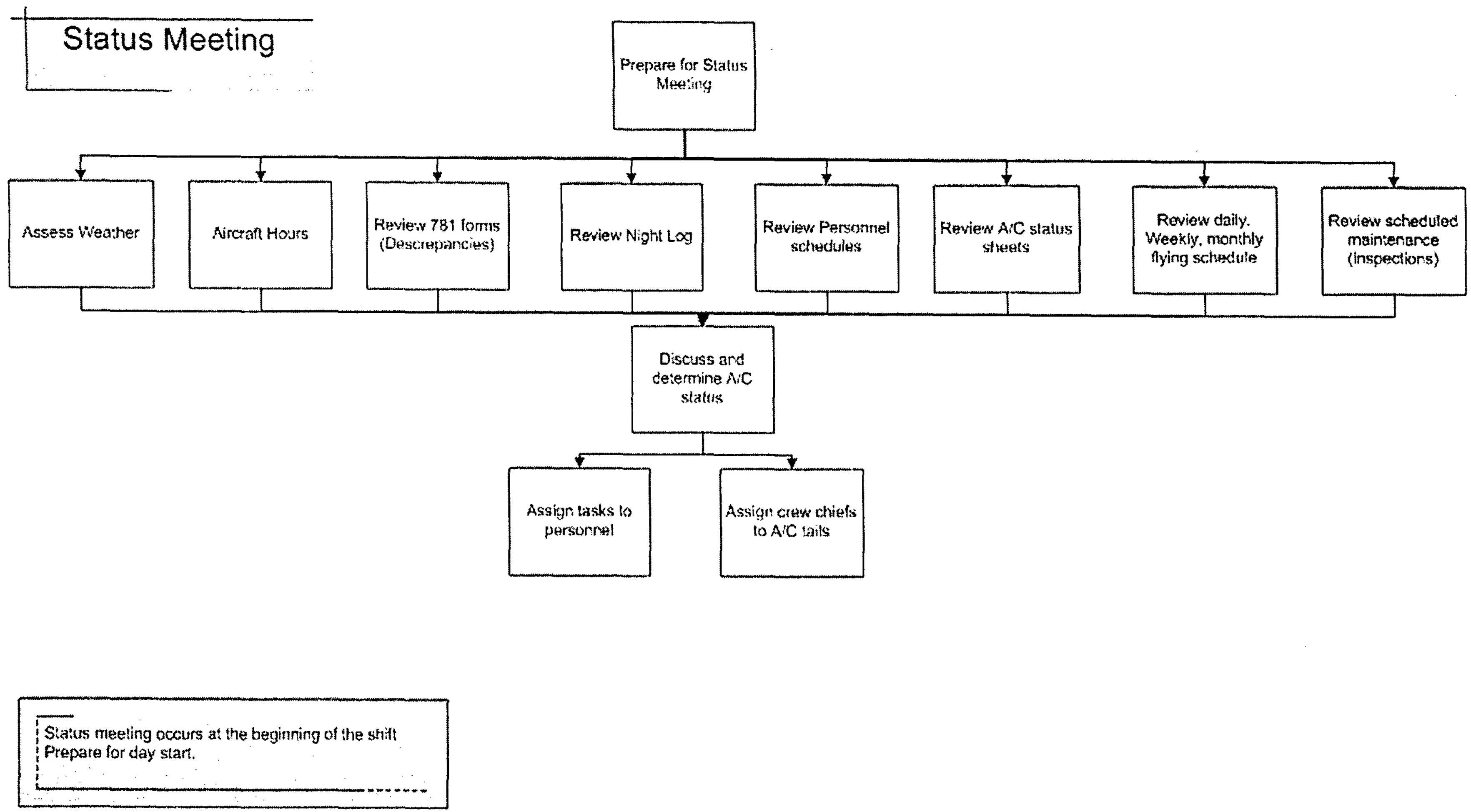


FIGURE 5: STATUS MEETING TASK BREAKDOWN

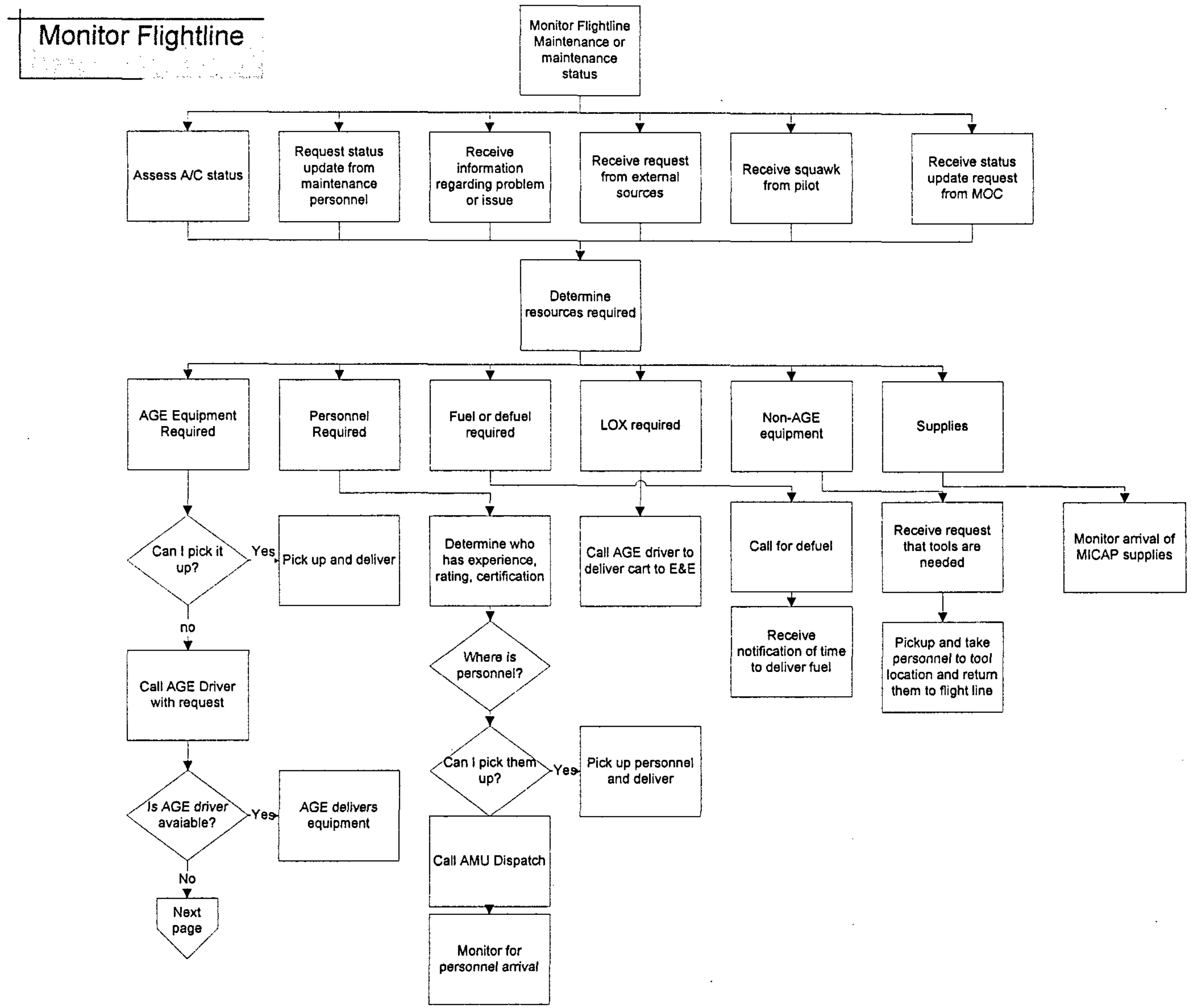


FIGURE 6: MONITOR FLIGHTLINE TASK BREAKDOWN (CONTINUES NEXT PAGE)

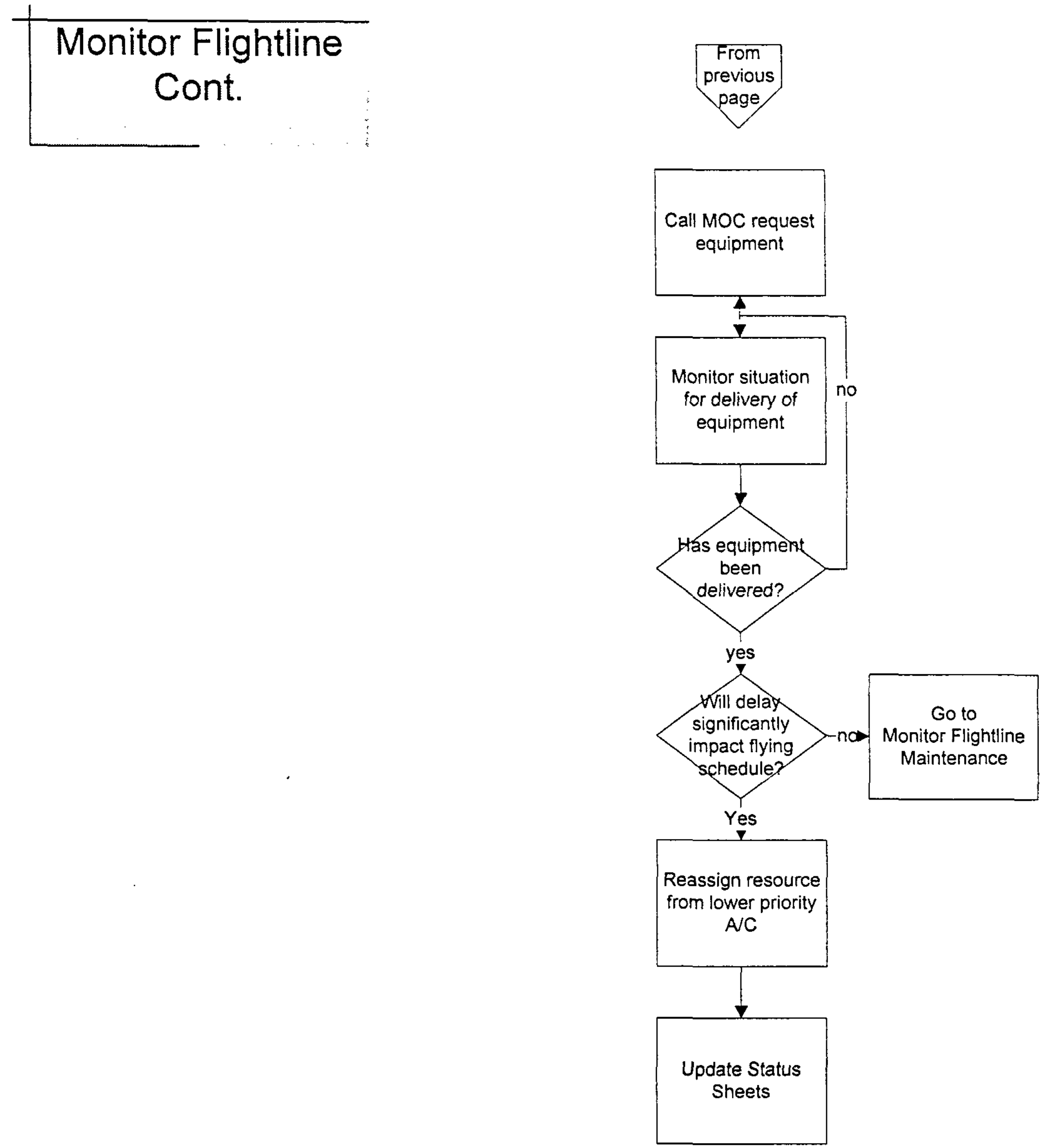


FIGURE 7: MONITOR FLIGHTLINE TASK BREAKDOWN (CONTINUED)

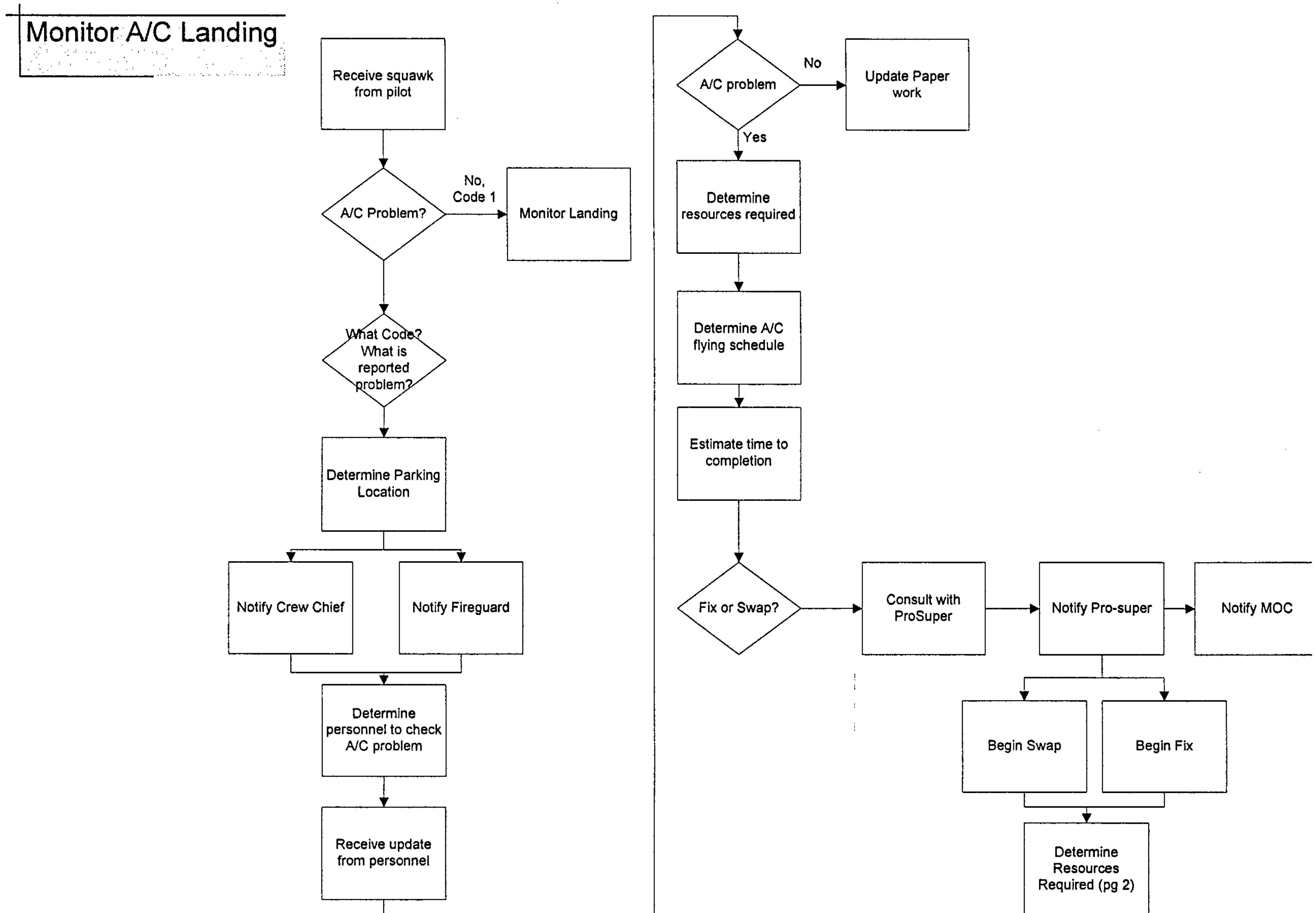


FIGURE 8: MONITOR AIRCRAFT LANDING TASK BREAKDOWN

FIGURE 9: MONITOR AIRCRAFT LAUNCH TASK BREAKDOWN

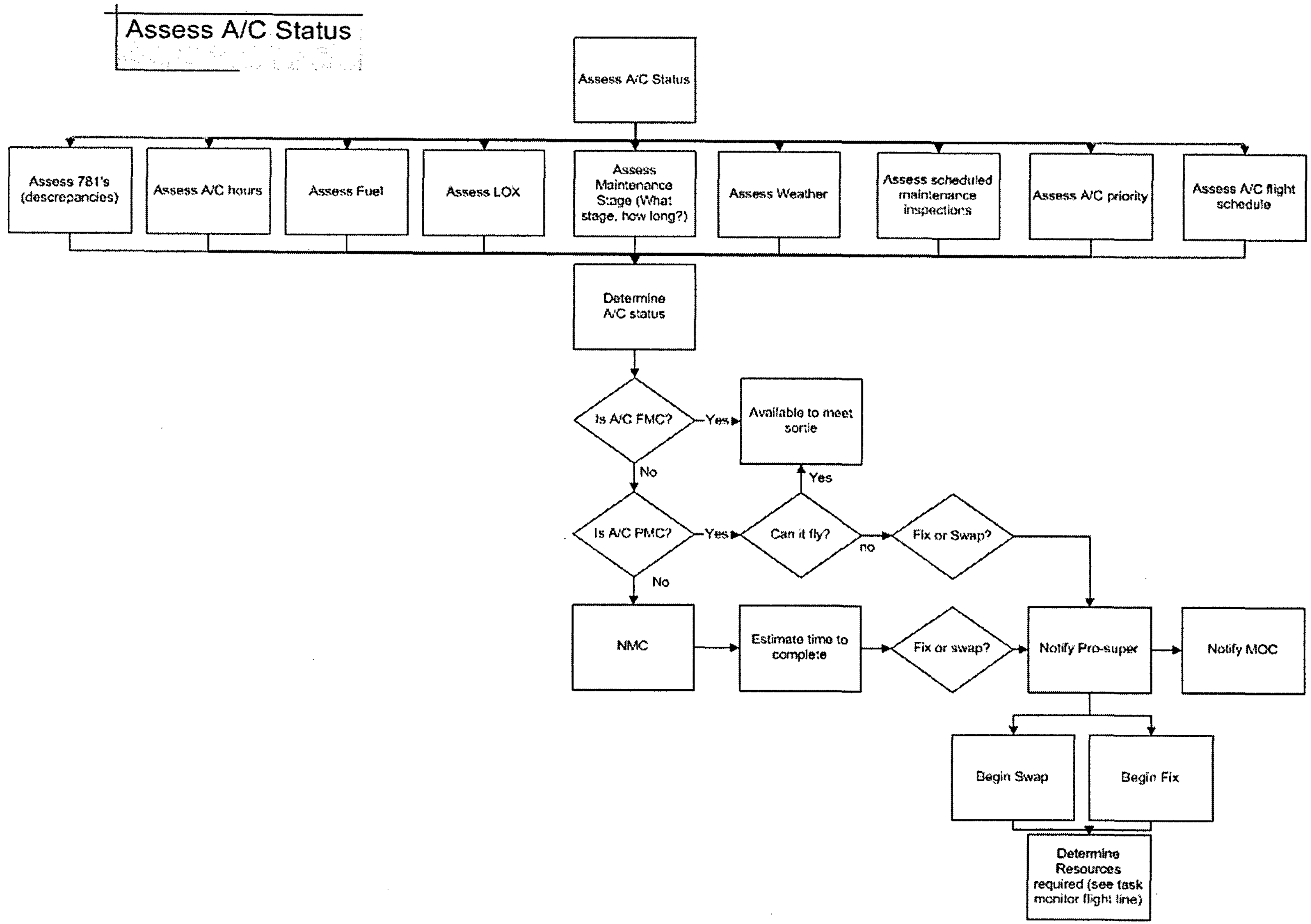


FIGURE 10: ASSESS AIRCRAFT STATUS TASK BREAKDOWN

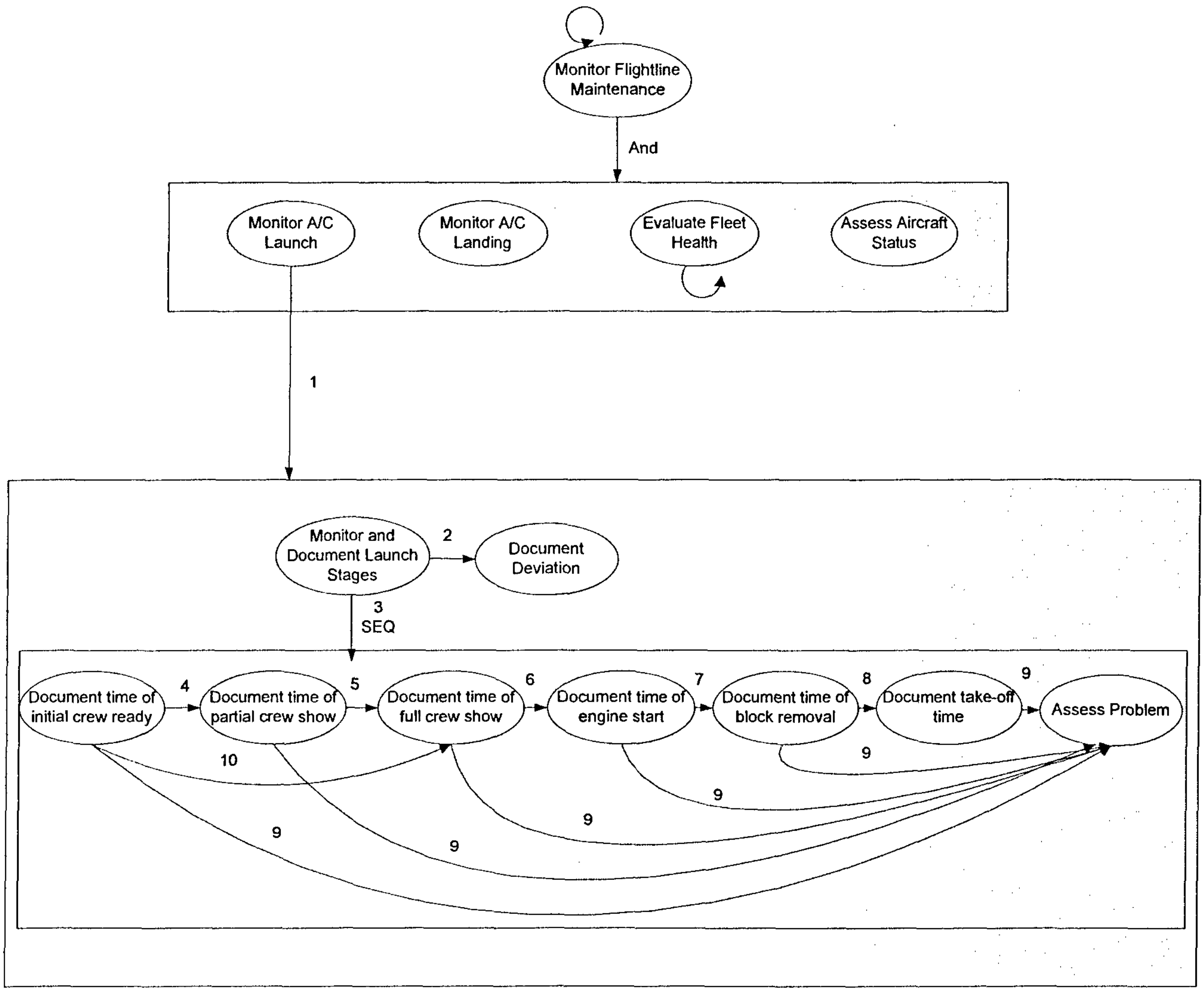
2.3.2 Operator Function Models

An Operator Function Model (OFM) supplemented with COGnitive information (OFM-COG) was created to present the Expeditor's Cognitive Model [10]. For the OFM 5 sub-functions of the Monitor Flightline Maintenance were identified: Monitor aircraft launch, Monitor aircraft landing, Assign aircraft to sorties, Assess aircraft status, and Evaluate fleet health (Figures 11-14). Tables 5-10 illustrate the OFM Cognitive Task Analysis. Information related to evaluating fleet health was not collected. Table 4 identifies the definitions for the Task agents used in this model.

TABLE 4: MILLERS COGNITIVE TASK TRANSACTIONS

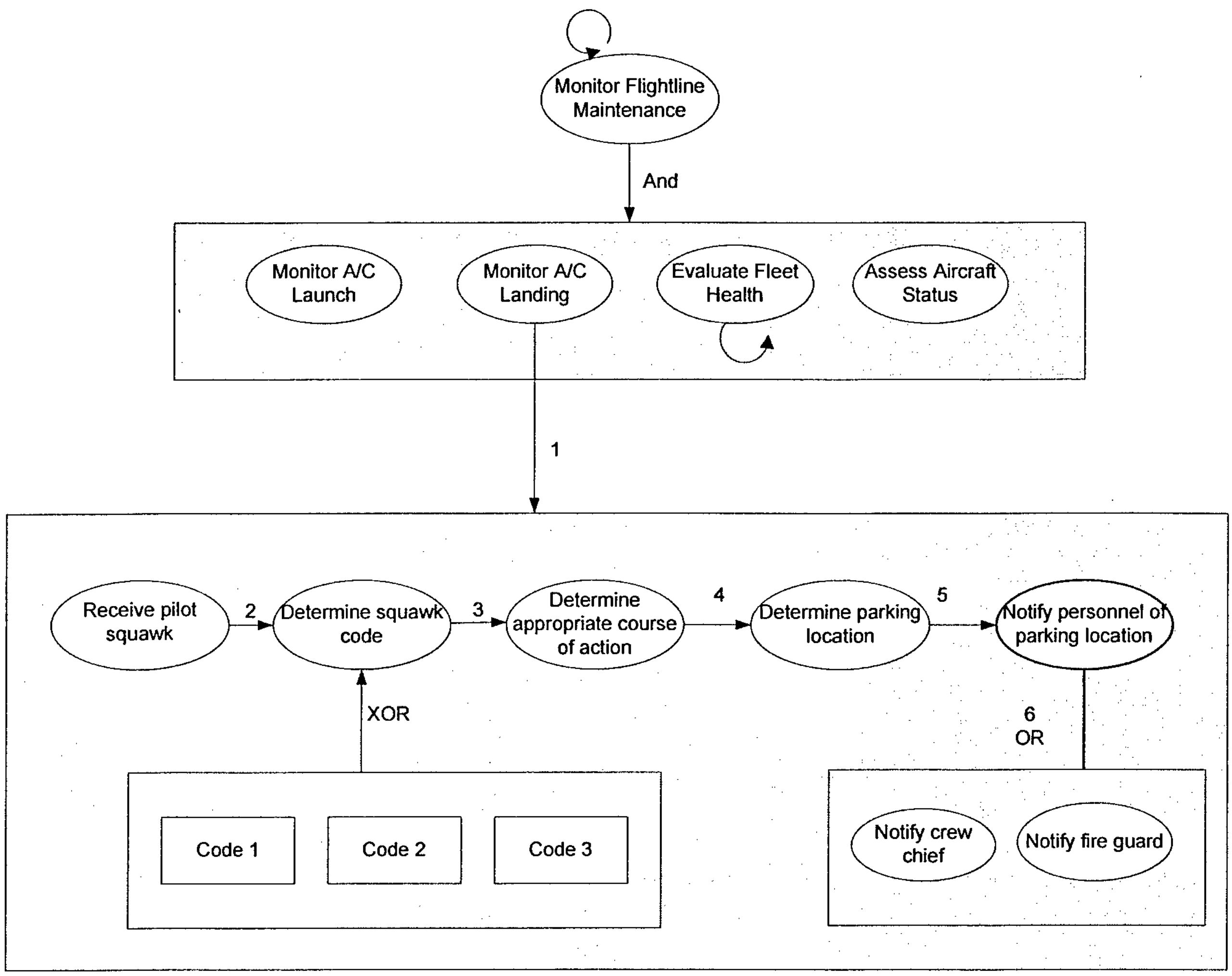
Cognitive Task Agent	Definition	Human Information Processing Resources
Adapt/Learn	Making and remembering new responses to a learned situation	Long term memory
Categorize	Defining and naming a group of things	Perceptual sensitivity, Long term memory
Code	Translating the same thing from one form to another	Long term memory, Working memory, Response precision
Compute	Figuring out a logical or mathematical answer to a defined problem	Working memory, Processing strategies
Control	Changing an action according to plan	Response precision
Count	Keeping track of how many	Sustained attention, Working memory,
Decide/select	Choosing a response to fit the situation	Long term memory, Processing strategies
Detect	Is something there?	Perceptual sensitivity, Distributed attention
Display	Showing something that makes sense	Response precision
Edit	Arranging or correcting things according to rules	Selective attention, Long term memory,
Filter	Straining out what does not matters	Selective attention
Goal image	A picture of a task well done	Long term memory, Processing strategies
Identify	What is it and what is its name?	Perceptual discrimination, Long term memory, Working memory,

Cognitive Task Agent	Definition	Human Information Processing Resources
Input Select	Select something to pay attention to or next	Selective attention, Perceptual sensitivity,
Interpret	What does it mean?	Sustained attention, Long term memory,
Message	A collection of symbols sent as a meaningful statement	Response precision
Plan	Matching resources in time to expectations	Working memory, Processing strategies
Purge	Getting rid of the irrelevant data	Selective attention
Queue to channel	Lining up to process in the future	Working memory, Processing strategies
Reset	Getting ready from some different action	Selective attention, Response precision,
Search	Looking for something	Perceptual sensitivity, Sustained attention,
Store	Keeping something intact for future use	Long term memory, Working memory
Store in buffer	Holding something temporarily	Working memory, Processing strategies
Test	Is it what it should be?	Perceptual sensitivity, Long term memory, Working memory
Transmit	Moving something from one place to another	Response precision



1. Aircraft to launch
2. Deviation occurred
3. Launch began
4. Crew signals ready
5. Partial crew arrived
6. Full crew arrived
7. Pilot starts engine
8. Blocks removed
9. A/C take-off
10. Full crew arrived

FIGURE 11: MONITOR AIRCRAFT LAUNCH OFM



1. Aircraft is landing
2. Squawk received
3. Identified code
4. Safety and rules considered
5. Parking location identified
6. Notify correct personnel

FIGURE 12: MONITOR AIRCRAFT LANDING OFM

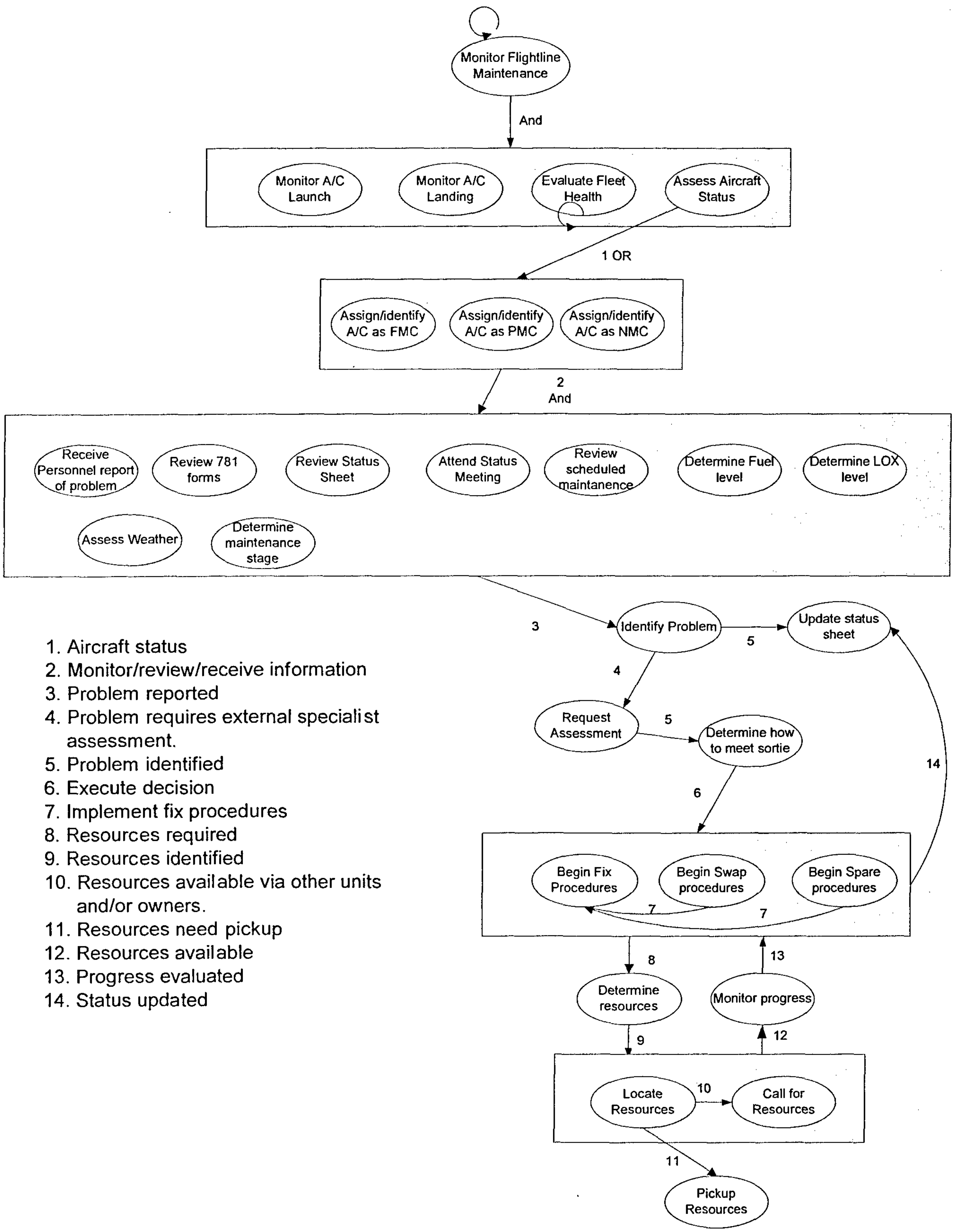
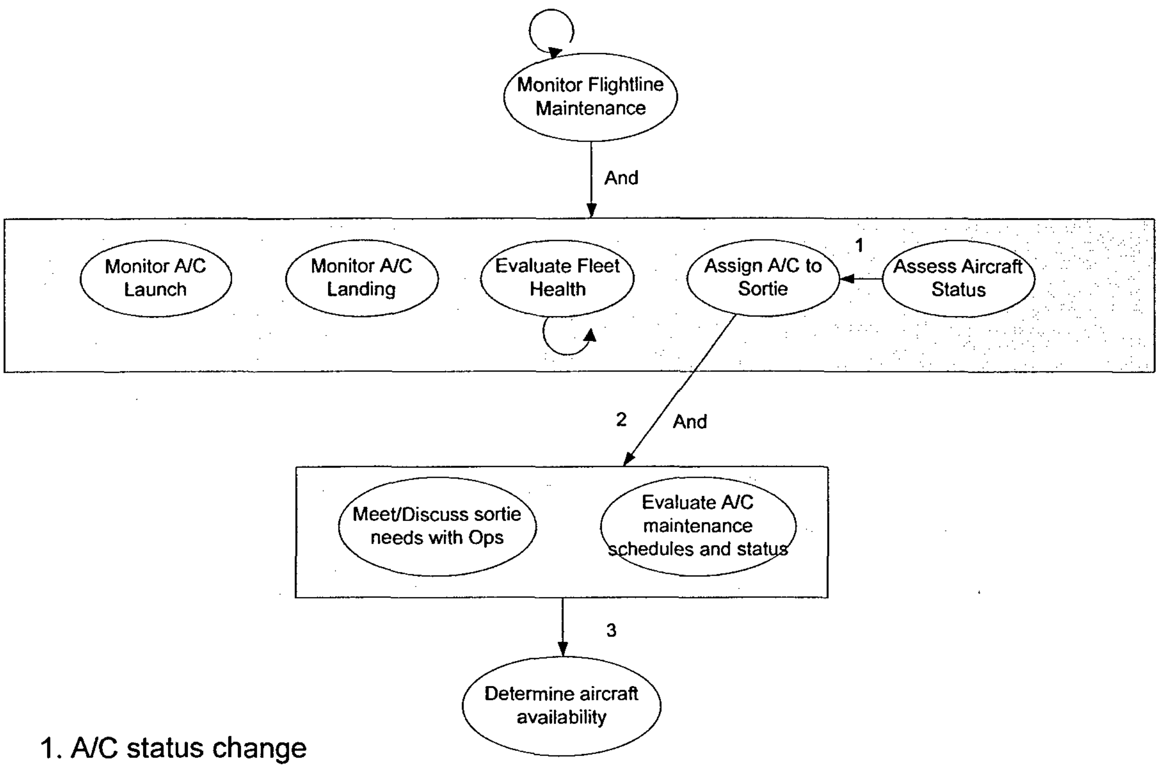


FIGURE 13: ASSESS AIRCRAFT STATUS OFM



1. A/C status change
2. Sortie requested/scheduled
3. Aircraft status identified

FIGURE 14: ASSIGN AIRCRAFT TO SORTIE OFM

TABLE 5: "MONITOR AIRCRAFT LAUNCH" FUNCTION OFM-COG ANALYSIS

OFM Function/Sub-function	**Cognitive Agent Tasks**	**Input**	**Human Information Processing Resources**	**Output**	**Task and Environmental Demand**
Monitor A/C Launch	Input Select	Aircraft schedule Radio Visual detection	Selective attention Long term memory	Attention to take-off stages	Number of A/C launching
	Identify	Take-off stage (crew ready, partial and full crew show, Engine Start, Block, Take off)	Perceptual discrimination, Long term memory, working memory	Document times (manual) Determine potential problem, severity	A/C and/or personnel problem during launch
	Interpret	Potential problem	Long term memory, Sustained attention	Potential course of action, merit of alternatives	Type and severity of problem, safety rules
	Decide/Select	Potential course of action, merit of alternatives	Long term memory, Processing strategy	Write-up deviation (manual), Communicate plan	Type and severity of problem, safety rules

TABLE 6: "MONITOR AIRCRAFT LANDING" FUNCTION OFM-COG ANALYSIS

OFM Function/Sub-function	**Cognitive Agent Tasks**	**Input**	**Human Information Processing Resources**	**Output**	**Task and Environmental Demand**
Monitor Aircraft Landing	Input Select Detect	Radio - pilot squawk, A/C schedule	Selective attention, Perceptual sensitivity	Squawk code	Deployed war time environment, safety of personnel
	Identify	Squawk Code	Perceptual discrimination, long term memory, Working memory	Severity and type of problem	Type and severity of problem, safety rules

OFM Function/Sub-function	Cognitive Agent Tasks	Input	Human Information Processing Resources	Output	Task and Environmental Demand
	Interpret	Severity and type of problem, Rules	Long term memory Sustained attention	Potential course of action, merit of alternatives	Type and severity of problem, safety rules, expertise, number of viable alternatives
	Decide/Select	Potential course of action, merit of alternatives	Long term memory, Processing strategy	Parking location identify, appropriate personnel notified	Type and severity of problem, safety rules, number of viable alternatives

TABLE 7: "ASSESS AIRCRAFT STATUS" FUNCTION OFM-COG ANALYSIS

OFM Function/Sub-function	Cognitive Agent Tasks	Input	Human Information Processing Resources	Output	Task and Environmental Demand
Assess Aircraft Status	Input select	Status sheet, Maintenance sheets, Radio, Personnel communication, weather, Visual inspection	Selective attention Perceptual sensitivity	Aircraft status code, A/C to monitor	Number of A/C to be monitored, Deployed war time environment, Time critical missions, mission priority
	Identify	Aircraft status code, A/C to monitor	Perceptual discrimination, long term memory, working memory	Identification of problems, issues, current state within maintenance processes	Expertise, Number of items to identify
	Interpret	Identification of specific problems, issues, current state within processes	Long term memory, sustained attention	Narrowing of issues	Number of problems, problem complexity

OFM Function/Sub-function	Cognitive Agent Tasks	Input	Human Information Processing Resources	Output	Task and Environmental Demand
Identify Problem	Transmit	Narrowing of issues	Response precision	Request and receive problem assessment, narrow issues	Expertise, Correct problem assessment, complete assessment
Determine how to meet sortie	Plan	Problem assessed	Working memory, processing strategy	Determine courses of action and merit of alternatives.	Current and future A/C schedules, resources
	Compute	Courses of action, merit of alternatives	Processing strategies, working memory	Compute time to fix or swap the A/C. Determine if sortie will be met. ETIC	Expertise, knowledge of tasks required, knowledge of time to complete tasks
	Decide/select	Computed time to fix or swap the A/C. Determine if sortie will be met. ETIC	Long term memory, Processing strategy	Decision to fix A/C, or swap aircraft?	Expertise Aircraft availability Impact on flying schedule
	Plan	Decision to fix/swap	Working memory, processing strategy	Plans for resources required to fix and swap aircraft.	Expertise, Number of resources and their status
	Search	Decision to fix/swap Plans to carryout decisions made	Sustained attention, perceptual sensitivity	Locating resources needed	Knows what resources are required
	Transmit Store	Resources located	Response precision	Transmit decision and plans to appropriate resources. Update status sheet, Update A/C status	Ability to transmit information to appropriate personnel
	Adapt/learn	Unique problem	Long term memory	New knowledge	Recognize unique or first experience with problem.

TABLE 8: " ASSIGN AIRCRAFT TO SORTIE" FUNCTION OFM-COG ANALYSIS

OFM Function/Sub-function	Cognitive Agent Tasks	Input	Human Information Processing Resources	Output	Task and Environmental Demand
Assign aircraft to sortie	Input Select	Operations request, Update of aircraft status	Selective attention	Sortie scheduled	Number of A/C available, deployed war time environment, time critical missions, mission priority
	Plan	Sortie scheduled	Working memory, processing strategy	Determine alternatives for a/c to meet sorties and merits of alternatives	Type of mission, A/C availability, maintenance schedules, Expertise
	Decide/Select	Alternative plans determined	Long term memory, Processing strategy	Assignment of A/C to sortie	Number of alternatives, Expertise

3 Scientific Study Results and Discussion

3.1 SPIRAL ONE POST TEST RANKING DECISION AND INFORMATION TABLES

Participants were asked to complete questionnaires at the end of the Scientific Study to obtain feedback on information helpful in making flightline decisions. Below are detailed frequency tables which are summarized in the main document.

3.1.1 Decision Elements Rankings

Post study questionnaire Part 2 requested participants to assign a rating indicating the importance of certain information on decisions. In the first half of the questionnaire participants rated 7 information elements (1-not at all important to 7-extremely important) on their fix/swap decision. The detailed frequency data is displayed in Tables 9-12.

TABLE 9: DECISIONS THAT IMPACT FSE, AA AND MC RATES

	1 Not at all Important	2 Somewhat Important	3 Slightly Unimportant	4 Neutral	5 Slightly Important	6 Somewhat Important	7 Extremely Important
Fix or Swap?				1	1	4	8
How should A/C be assigned for the week?		1			6	6	1
How should today's flying schedule be changed?				1	3	2	7
How will aircraft be assigned for the month?	1			4	7	1	
Should we CANN?				2	1	6	5
Should the flight be delayed?					2	5	7
What personnel should be assigned to maintenance tasks?				1	4	5	4
Which aircraft should be assigned to which sortie?				1	1	6	6

TABLE 10: INFORMATION INFLUENCING THE FIX OR SWAP DECISION

Information Influencing the Fix or Swap Decision - Airlift and Fighter Combined							
	1 Not at all Important	2 Somewhat Unimportant	3 Slightly Important	4 Neutral	5 Slightly Important	6 Somewhat Important	7 Extremely Important
A/C Availability Metric			1	2		2	7

Information Influencing the Fix or Swap Decision - Airlift and Fighter Combined							
	1 Not at all Important	2 Somewhat Unimportant	3 Slightly Important	4 Neutral	5 Slightly Important	6 Somewhat Important	7 Extremely Important
Flying Schedule Effectiveness (FSE) Rate	1	1	1	3	1	3	1
MC Rate	1			4	3	3	3
Monthly Flying Schedule	1	1	1	4	7		
Today's Flying Schedule							14
Tomorrow's Flying Schedule				1	3	5	5
Weekly Flying Schedule		2		1	4	7	

TABLE 11: INFORMATION INFLUENCING THE FIX OR SWAP DECISION - AIRLIFT ONLY

Information Influencing the Fix or Swap Decision - Airlift Only							
	1 Not at all Important	2 Somewhat Unimportant	3 Slightly Important	4 Neutral	5 Slightly Important	6 Somewhat Important	7 Extremely Important
A/C Availability Metric			1	1		1	5
Flying Schedule Effectiveness (FSE) Rate	1	1	1	2	1	2	
MC Rate	1			2		3	3
Monthly Flying Schedule	1	1		3	4		
Today's Flying Schedule							9
Tomorrow's Flying Schedule				1		4	4
Weekly Flying Schedule		1			3	5	

TABLE 12: INFORMATION INFLUENCING THE FIX OR SWAP DECISION - FIGHTER ONLY

Information Influencing the Fix or Swap Decision - Fighter Only							
	1 Not at all Important	2 Somewhat Unimportant	3 Slightly Important	4 Neutral	5 Slightly Important	6 Somewhat Important	7 Extremely Important
A/C Availability Metric				1		1	2
Flying Schedule Effectiveness (FSE) Rate				1		1	1
MC Rate				2	3		
Monthly Flying Schedule			1	1	3		
Today's Flying Schedule							5
Tomorrow's Flying Schedule					3	1	1
Weekly Flying Schedule		1		1	1	2	

3.1.2 Data Elements Frequency Tables

The Scientific Study questionnaires asked participants to rate on a scale of 1 to 7, the importance of data elements that would be available in an electronic decision support tool. The data elements were broken into five categories: Aircraft, Personnel, AGE, Supply, and Other. They were also asked to write in any data elements they considered important. Tables 13-17 provide the detailed frequency information related to these data elements.

TABLE 13: IMPORTANT AIRCRAFT DATA ELEMENTS

Important Aircraft Data Elements							
	1 Not at all Important	2 Somewhat Important	3 Slightly Important	4 Neutral	5 Slightly Important	6 Somewhat Important	7 Extremely Important
781 Discrepancies					1	5	8
Aircraft Configuration						3	9
Aircraft Hours	1	1	2	3	6	1	
Aircraft Maintenance History		2	1	4	2	4	1
CAMS 380 List of Jobs				1	3	7	2
Current status of Aircraft (FMC, NMC, PMC, etc.)							14
Engine Hours and Cycles	1	2	3	2	4	1	1
Location of Aircraft				1		2	11
Monthly Aircraft Scheduled Maintenance		1		2	5	4	2
Monthly Flying Schedule		1		3	8	2	
Time since last Phase/ISO Inspection	1	1	2	2	4	2	2
Weekly Aircraft Schedule Maintenance				2	1	8	3
Weekly Flying Schedule				2		8	4

TABLE 14: IMPORTANT AGE DATA ELEMENTS

	1 Not at all Important	2 Somewhat Important	3 Slightly Unimportant	4 Neutral	5 Slightly Important	6 Somewhat Important	7 Extremely Important
107 Requests	1	1	3	2	1	3	
Battery Level on Equipment	1		2	3	3	4	1
Fuel Level on Powered Equipment			1	3	2	7	1
Level of Liquid Oxygen					1	7	6
Location of AGE and other equipment			1	1	1	5	6

	1 Not at all Important	2 Somewhat Important	3 Slightly Unimportant	4 Neutral	5 Slightly Important	6 Somewhat Important	7 Extremely Important
Status of AGE Equipment (FMC/NMC)			1	1		5	7

TABLE 15: IMPORTANT SUPPLY DATA ELEMENTS

	1 Not at all Important	2 Somewhat Important	3 Slightly Unimportant	4 Neutral	5 Slightly Important	6 Somewhat Important	7 Extremely Important
350 Tag			2	4	5	1	
Bench Stock				3		7	4
Location of MICAP Supply						10	4
Location of Supplies				1	1	9	3
Status of MICAP Supply					2	4	7
Status of Supplies				1	3	3	7

TABLE 16: IMPORTANT PERSONNEL DATA ELEMENTS

Important Personnel Data Elements							
	1 Not at all Important	2 Somewhat Important	3 Slightly Unimportant	4 Neutral	5 Slightly Important	6 Somewhat Important	7 Extremely Important
Location of Personnel Resources						4	9
Monthly Personnel Schedules		2		4	6	2	
Personnel Qualifications Specialty					2	4	8
Personnel Qualifications Certifications					1	3	10
Personnel Qualifications Ranks		1		1	2	5	5
Personnel Qualifications Skill Level (3.5.7)					1	2	11
Personnel Status						7	6
Special Certification Rosters (Red X, ER, intake)						2	12
Weekly Personnel Schedules				3	2	8	1

TABLE 17: OTHER IMPORTANT DATA ELEMENTS

Other Important Data Elements							
	1 Not at all Important	2 Somewhat Important	3 Slightly Unimportant	4 Neutral	5 Slightly Important	6 Somewhat Important	7 Extremely Important
Squadron Unit monthly analysis indicators report		1	1	6	1	3	
Weather				1		3	10

3.2 VERBAL PROTOCOL ANALYSIS

Participants were asked to think aloud during each Scientific Study scenario as a first step in the verbal protocol analysis as explained in Section 5.6 of the SSLC2 Final Report. Their verbal statements were recorded and notes were taken in real time. The verbal information for fifteen subjects were evaluated, across all three conditions resulting in analysis of 45 scenarios. Table 18 below is an example of the data collection template. This example is from the WhereNet condition during the fix/swap decision. The data were analyzed in several different ways. First the information was broken into steps. For each step, the verbal information was dissected into six categories. The first category is **Information**. This category refers to the type of information the participant was seeking, distributing or working with during the step. The second category is **Source**, which refers to where they were seeking the information. The third category is **Destination**, referring to where the participant sent or distributed the information. The fourth category is **Decision** which indicates what decision they were working on. The fifth category is **Time**, which was used to input the time to site or time to fix information that participant provided during the scenario. The sixth category is **Process** which is a description of steps or the process the participants were taking.

TABLE 18: VERBAL PROTOCOL DATA COLLECTION EXAMPLE

Step	Information	Source	Destination	Decision	Time	Process & Analysis
1	Current Time and Task	Scenario		Fix/Swap		Since the Air Crew had already arrived at the plane, the participant knew he had to go to the spare.
2	Current Task	Scenario		Fix Swap		
3	Crew Status		Specialist Expeditor	Fix/Swap		He told the specialist to send the Air Crew to 1463.
4	Resources Needed	Specialist				The participant asked the specialist who he needed for the fix – jack team, weapons download, is defuel needed.
5	Task Assignment		Weapons			He called weapons to download the cargo
6	Task Clarification	Crew Chief Expeditor		Defuel Needed?		He asked the crew chief expeditor if a defuel was needed – just a jack was needed
7	Equipment Availability	Maintenance Supervisor		Resource Availability		He asked the maintenance super if the jack crew and jacks are available
8	Resource Location	WhereNet		Resource Location		He went to WN JA* in fighter resources and finds Jacks on the map
9	Resource Location		AGE	Resource Location		He told AGE to get the jacks
10	Resource Location		Specialist	Resource Location	15	He let the specialist know jacks were on their way in 15 minutes
11	Time to Fix				MD	Did not Provide an ETIC

3.2.1 Information Frequency

The types of information the participants used during the task were determined and a frequency count was tabulated showing how often the information was referred to or used across all fifteen subjects and three conditions (45 scenarios). Table 19 provides the frequency count data and categories of information. The data helps to determine the type of information the participants needed to complete the tasks.

TABLE 19: INFORMATION FREQUENCY TABLE

Condition	Information	Count Of Information
Baseline Experiment		
Baseline Experiment	A/C Availability	2
Baseline Experiment	A/C Configuration	3
Baseline Experiment	A/C Parking	1
Baseline Experiment	A/C Problem	1
Baseline Experiment	A/C Status	8
Baseline Experiment	Current Time	8
Baseline Experiment	Entry Control Point	2
Baseline Experiment	Equipment Allocation	15
Baseline Experiment	Equipment Availability	10
Baseline Experiment	Equipment Location	4
Baseline Experiment	ETIC	11
Baseline Experiment	Flightline Status	1
Baseline Experiment	Fuel	2
Baseline Experiment	Hangar Status	1
Baseline Experiment	Job Number	1
Baseline Experiment	Mission	1
Baseline Experiment	Part Availability	4
Baseline Experiment	Personnel Allocation	10
Baseline Experiment	Personnel Availability	17
Baseline Experiment	Personnel Location	8
Baseline Experiment	Personnel Qualifications	1
Baseline Experiment	Protocol	1
Baseline Experiment	Resource Allocation	1
Baseline Experiment	Resource Availability	2
Baseline Experiment	Resource Problem	1
Baseline Experiment	Schedule Change	7
Baseline Experiment	Swap	13
Baseline Experiment	T/O time	7

Condition	Information	Count Of Information
Baseline Experiment	Task Assignment	12
Baseline Experiment	Task Sequence	3
Baseline Experiment	Task Time	4
Baseline Experiment	Time to Fix	21
Baseline Experiment	Time to Site	31
Baseline Experiment	Tow Clearance	1
Baseline Experiment	Weather	2
Smart Systems Experiment		0
Smart Systems Experiment	A/C Availability	4
Smart Systems Experiment	A/C Configuration	1
Smart Systems Experiment	A/C Problem	9
Smart Systems Experiment	A/C Status	6
Smart Systems Experiment	Current Task	1
Smart Systems Experiment	Current Time	2
Smart Systems Experiment	Equipment Allocation	2
Smart Systems Experiment	Equipment Availability	2
Smart Systems Experiment	Equipment Location	15
Smart Systems Experiment	ETIC	3
Smart Systems Experiment	Flight Schedule	2
Smart Systems Experiment	Flightline Status	8
Smart Systems Experiment	Fuel	2
Smart Systems Experiment	Mission	1
Smart Systems Experiment	Part Availability	1
Smart Systems Experiment	Personnel Allocation	2
Smart Systems Experiment	Personnel Availability	6
Smart Systems Experiment	Personnel Location	12
Smart Systems Experiment	Resource Allocation	1
Smart Systems Experiment	Resource Location	1
Smart Systems Experiment	Resources needed	1
Smart Systems Experiment	Swap	8
Smart Systems Experiment	T/O Time	6
Smart Systems Experiment	Task Sequence	1
Smart Systems Experiment	Time to Fix	18
Smart Systems Experiment	Time to Site	32
Smart Systems Experiment	Time to Swap	5
Smart Systems Experiment	Weather	2
WhereNet Experiment		0
WhereNet Experiment	A/C Availability	3
WhereNet Experiment	A/C Configuration	1

Condition	Information	Count Of Information
WhereNet Experiment	A/C Parking	1
WhereNet Experiment	A/C Problem	5
WhereNet Experiment	A/C Status	8
WhereNet Experiment	Coordination	1
WhereNet Experiment	Crew Status	1
WhereNet Experiment	Current Task	1
WhereNet Experiment	Current Time	5
WhereNet Experiment	Entry Control Point Location	1
WhereNet Experiment	Equipment Allocation	15
WhereNet Experiment	Equipment Availability	6
WhereNet Experiment	Equipment Location	24
WhereNet Experiment	Equipment Movement	1
WhereNet Experiment	ETIC	10
WhereNet Experiment	Flight Schedule	1
WhereNet Experiment	Fuel	4
WhereNet Experiment	Hangar Status	1
WhereNet Experiment	Job Control Number	2
WhereNet Experiment	Part Availability	2
WhereNet Experiment	Personnel Allocation	15
WhereNet Experiment	Personnel Availability	5
WhereNet Experiment	Personnel Location	18
WhereNet Experiment	Protocol Information	1
WhereNet Experiment	Resource Allocation	4
WhereNet Experiment	Resource Availability	3
WhereNet Experiment	Resource Location	3
WhereNet Experiment	Resources Needed	1
WhereNet Experiment	Schedule Change	5
WhereNet Experiment	Swap	8
WhereNet Experiment	T/O Time	6
WhereNet Experiment	Task Assignment	10
WhereNet Experiment	Task Clarification	1
WhereNet Experiment	Task Time	1
WhereNet Experiment	Time to fix	18
WhereNet Experiment	Time to Site	38
WhereNet Experiment	Weather	3

3.2.2 Source Frequency

Where the participants sought information was documented and the frequency was tabulated. Table 20 illustrates this data.

TABLE 20: SOURCE FREQUENCY TABLE

Condition	Source	Count Of Source
Baseline Experiment		
Baseline Experiment	AGE	10
Baseline Experiment	AMU Dispatch	10
Baseline Experiment	Base Map	8
Baseline Experiment	Crew Chief	1
Baseline Experiment	Equipment Resource Sheets	2
Baseline Experiment	Expeditor	5
Baseline Experiment	Hydraulics Shop	1
Baseline Experiment	Maintenance Supervisor	2
Baseline Experiment	MOC	6
Baseline Experiment	Munitions	5
Baseline Experiment	Personnel List	1
Baseline Experiment	Personnel Sheet	2
Baseline Experiment	PI	3
Baseline Experiment	Weather Card	1
Baseline Experiment	ProSuper	1
Baseline Experiment	Resource Sheet	5
Baseline Experiment	Scenario/PI	10
Baseline Experiment	Self	24
Baseline Experiment	Specialist	31
Baseline Experiment	Status Sheet/Schedule	16
Smart Systems Experiment		0
Smart Systems Experiment	Add Comparison: Drop Down	2
Smart Systems Experiment	AGE	1
Smart Systems Experiment	Base Map Paper	1
Smart Systems Experiment	Comparison Views	49
Smart Systems Experiment	Context View	1
Smart Systems Experiment	Fix Resources/ Problem Schedule View	1
Smart Systems Experiment	MOC	2
Smart Systems Experiment	Overview Geo/Schedule View	19
Smart Systems Experiment	Pop Up Box	1
Smart Systems Experiment	problem Geo View	5
Smart Systems Experiment	Problem Schedule View	27
Smart Systems Experiment	Scenario	2
Smart Systems Experiment	Schedule/Status Sheet	2
Smart Systems Experiment	Select Plan	11
Smart Systems Experiment	Self	1
Smart Systems Experiment	Smart Systems	10

Condition	Source	Count Of Source
Smart Systems Experiment	Smart Systems GeoView Context View Fix Resources	1
Smart Systems Experiment	Specialist	2
WhereNet Experiment		0
WhereNet Experiment	WhereNet	1
WhereNet Experiment	A/C Paperwork	1
WhereNet Experiment	AGE	7
WhereNet Experiment	AMU	4
WhereNet Experiment	Assumption	8
WhereNet Experiment	Base Map	3
WhereNet Experiment	Crew Chief	1
WhereNet Experiment	Expeditor	3
WhereNet Experiment	Fuel Specialist	1
WhereNet Experiment	Maintenance Supervisor	1
WhereNet Experiment	MOC	5
WhereNet Experiment	Scenario/PI	8
WhereNet Experiment	Schedule/Status Sheet	15
WhereNet Experiment	self	17
WhereNet Experiment	Specialist	32
WhereNet Experiment	WhereNet	40
WhereNet Experiment	WhereNet Code Sheet	1

3.2.3 Destination Frequency

Frequencies were determined for Destination, which refers to where the participant sent or distributed the information. This information can be found in Table 21.

TABLE 21: DESTINATION FREQUENCY TABLE

Condition	Destination	Count Of Destination
Baseline Experiment		
Baseline Experiment	AGE	13
Baseline Experiment	AMU Dispatch	10
Baseline Experiment	Fuels	1
Baseline Experiment	MOC	19
Baseline Experiment	Munitions	5
Baseline Experiment	PI	1
Baseline Experiment	ProSuper	5
Baseline Experiment	Secondary Expeditor	2
Baseline Experiment	Specialist	8
Baseline Experiment	Tow Team	1
Smart Systems Experiment		

Condition	Destination	Count Of Destination
Smart Systems Experiment	AGE	2
Smart Systems Experiment	AMU Dispatch	1
Smart Systems Experiment	MOC	1
WhereNet Experiment		
WhereNet Experiment	AGE	14
WhereNet Experiment	AMU Dispatch	6
WhereNet Experiment	Crew Chiefs	1
WhereNet Experiment	Expeditor	4
WhereNet Experiment	Maintenance Supervisor	2
WhereNet Experiment	MOC	16
WhereNet Experiment	Munitions	4
WhereNet Experiment	PI/Scenario	1
WhereNet Experiment	ProSuper	6
WhereNet Experiment	Specialist	0

Appendix C
SSLC2 Scenarios

TABLE OF CONTENTS

1 Introduction

SSLC2 Team members developed a series of scenarios highlighting common flightline problems requiring various personnel and equipment resources. The scenarios were developed with input from various Subject Matter Experts and were made to be as realistic as possible. These scenarios, detailed in this Appendix, became the basis for the Scientific Study simulation. Team members created four distinct scenarios detailing a fuel leak, gland nut crack, engine stall, and cockpit glass removal each tailored for both the airlift and fighter situations. The scenarios and associated data were presented to the scientific study participants through a script and set of procedures. Related data, such as personnel and resources, were presented through the WhereNet and SSLC2 technology conditions to enhance the scenarios.

2 Scenario 1: Left Main Strut – Airlifter (Tail #89-0449)

During the walk-around inspection, the crew reports hydraulic fluid on the left main strut. Thirty minutes earlier the Crew Chief had inspected the struts and found no trace of hydraulic fluid in that location. The Crew Chief calls the Expediter. The Expediter knows that in the worse-case scenario, they will need to change the strut. In order to change the strut, the aircraft will need to be defueled and jacked. That also means they will need a power unit, a hydraulic mule, a set of jacks (6 jacks), a jacking team (7 people), and a defuel team (3 people can be some of the same people as the jacking team), a defuel truck, and a jacking manifold. Also required will be a three person airfreight crew with a K-Loader to download the cargo, plus the pneudraulics technician to do the actual work as well as any subsequently discovered bad parts.

During troubleshooting the pneudraulics technician discovers the gland nut is cracked and must be changed (jacking and gear retraction will be required). He informs the Expediter and orders the part. The Expediter, who is somewhat relieved that the strut itself does not need to be changed, reports the problem to the production supervisor (ProSuper) and Maintenance Operations Center (MOC) requesting airfreight to download the cargo. Cargo download is a rather routine process and everything goes as expected. Without waiting for air freight to finish, the Expediter orders the defuel truck, the jacking

manifold, jacks, and hydraulic mule. They also need a power cart, but there is one already at the aircraft from take-off preparations. While air freight was in the process of removing the last of the cargo, the Expediter gets word the power cart just ran out of fuel. Some of the preparations can continue, but the power cart will be needed for defuel. Airfreight has completed their job in about 20 minutes.

Once the cargo has been unloaded, the Expediter drops off the jack team and instructs them to begin preparing for the jack job while waiting for defuel. The jacks can be positioned and connected to the jacking manifold and the pneudraulics lines from the mule can be connected to the aircraft.

The fuel truck and new power cart finally arrive and the aircraft defueled. As they begin sorting themselves out the jack crew suddenly realizes that none of them is jack supervisor qualified. The Expediter had expected the TSgt he dropped off to be the supervisor, but the TSgt recently crossed over from another airframe and has not yet been certified on everything. The problem now is that everyone else on the flightline seems to be busy with the morning launch and he needs to find another individual to supervise the jack job quickly!

A SSgt Crew Chief washing her aircraft at the wash rack is jack supervisor qualified, so the TSgt goes quickly to relieve her. She arrives and the aircraft is jacked in short order. While the jacking commences, the Expediter contacts the specialist supervisor to call for the pneudraulics specialist to come out and get to work.

Finally the pneudraulics technician takes time to review the tech data and identify future road blocks. When all the parts are assembled and the aircraft has been jacked he and the Crew Chief begin. Once the gland nut is installed it is pressure checked and then a gear retraction check is made. Once everything is determined to be working properly, the aircraft is lowered to the ground and returned to flying condition.

3 Scenario 1: Left Main Strut – Fighter (Tail #85-1462)

During the walk-around inspection, the pilot reports hydraulic fluid on the left main strut. Thirty minutes earlier the Crew Chief had inspected the struts and found no trace of hydraulic fluid in that location. The Crew Chief calls the Expediter. The Expediter knows that in the worse-case scenario, they will need to change the strut. This means that

they will need to jack the aircraft and because of the heavy fuel load, the aircraft will need to be de-fueled before jacking. This job will require a power unit, a hydraulic mule, a set of jacks (3 jacks), a jacking team (4 people), a defuel team (3 people can be the same people as the jacking team), the defuel truck, plus an MC-7 cart to purge the drop tanks. Also required will be the weapons load crew to disarm and download the weapons as well as any subsequently discovered bad parts.

During troubleshooting the Crew Chief discovers that the gland nut is cracked and must be changed. Even though the strut itself is good, jacking and gear retraction will be required regardless. The Crew Chief informs the Expediter and orders the part. The Expediter has the weapons load crew safe the gun and download the munitions. This is a rather routine process and everything goes as expected. Without waiting for the load crew to finish, the Expediter orders the defuel truck, the MC-7 as well as the jacks and hydraulic mule. They also need a power cart and there were none on the ready line a few minutes ago, there is one sitting at the next aircraft, seemingly unneeded there. While the load crew was in the process of removing the last of the missiles, the Expediter gets the word from the Crew Chief that the power unit they pulled over from the adjacent spot is out of fuel. The load crew has completed their job in about 20 minutes.

Once the weapons are clear and the new power unit is in position, the Expediter drops off the three other people he recruited for the jack team and instructs them to begin preparing for the jack job while waiting for the defuel. The jacks can be positioned and the pneudraulics lines from the mule can be connected to the aircraft. The MC-7 is also put into place in preparation for the defuel operation.

The empty truck arrives and the aircraft defueled. The jack crew suddenly realizes that none of them is jack supervisor qualified. The Expediter had expected the TSgt he dropped off to be the supervisor, but the TSgt recently crossed over from another airframe and has not yet been certified on everything. The problem now is that everyone on the flightline seems to be busy with the morning launch and he needs to find another individual to supervise the jack job quickly!

The Aircraft Maintenance Unit (AMU) dispatch position (a rotating duty) is currently being manned by a SRA who is jack supervisor qualified and so the TSgt quickly goes into the AMU and relieves her. She arrives and the aircraft is jacked in short order.

Finally the Crew Chief has the time to review the tech data to identify future road blocks. When all the parts are assembled and the aircraft has been jacked he and another Crew Chief begin the repair. Once the gland nut is installed it is pressure checked and then a gear retraction check is made. Once everything is determined to be working properly, the aircraft is lowered to the ground and returned to flying condition.

4 Scenario 2: Cockpit Glass – Airlifter (Tail # 89-0452)

During the Crew Chief's preflight cockpit glass cleaning, she notices a crack along the base of the window. The crack is aligned with the cockpit glass frame so as to make discovery unlikely unless closely inspected. After a quick check of the technical order (TO), she believes that the crack is beyond limits and the glass must be changed. The Expediter is called and the situation is assessed. If the cockpit glass does indeed need to be changed, they will have to tow the aircraft into a hangar as changing the glass outdoors is not an option today with the wind and rain currently falling. In addition to the tow tractor, tow bar and tow crew they will also need the sheet metal technician to evaluate the problem, the Aerospace Repair (AR) technician to change the glass, a B-4 Stand, and another piece of glass. Environmental & Electrics (E&E) technicians will be required to perform a continuity check on the window heating element prior to sealing the window. A heater might also be necessary to help cure the sealant. After the glass change is complete, a pressurization cart, and the E&E technician will be needed to perform the pressure check.

Sheet metal technicians determine that the glass must be changed. They inform the Expediter and the glass is ordered. The Expediter checks with the MOC to determine a hangar location for the glass change since inclement weather is present. The Expediter orders the tow operation preparation and requests the AR technicians meet the aircraft at the hangar.

The tow begins and the aircraft is quickly pushed into the waiting hangar. AR arrives with the new glass and completes the removal and replacement of the glass and calls for E&E to come perform the continuity check. E&E arrive and begin setting up for the check when the Specialist Expediter arrives and shouts that they have an E&E red ball on another aircraft. Enroute the Specialist Expediter calls the Crew Chief Expediter to

suggest he look for one of the other E&E troops on duty to ohm out the window. Another E&E troop arrives and the continuity check is completed.

AR applies the sealant and the cure begins. There is a heater just outside the hangar door and the crew chief connects the hose extenders so that the heater can be used to speed the cure. After just a few minutes the heater quits and although there is plenty of fuel, it just won't start again. The Crew Chief flags down the specialist truck to report the situation to the Expediter. Another heater is brought out. In a few hours the sealant is cured and the aircraft is ready for pressure testing. The Expediter calls for the E&E tech and the pressurization cart. The E&E technician makes it back to the aircraft and the pressure check is completed with no discrepancies.

5 Scenario 2: Canopy Glass – Fighter (Tail # 85-1459)

During the Crew Chief's preflight canopy cleaning, she notices a crack along the base of the window. The crack is aligned with the canopy frame so as to make discovery unlikely unless closely inspected. She believes that the crack is beyond limits and the canopy must be changed. The Expediter is called and the situation is assessed. If the canopy does indeed need to be changed, they will have to tow the aircraft into a hangar as changing the canopy outdoors is not reasonable because it is raining and the wind is blowing. In addition to the tow tractor, tow bar and tow crew they will also need the sheet metal technician to evaluate the problem and change the glass (if necessary), egress technicians to disarm the ejection seat and remove the canopy, the canopy hoist, the canopy jig, and another canopy glass. Also, a weapons load crew will be needed to disarm the aircraft and download the weapons. After the canopy change is complete, a pressurization cart and the Environmental & Electrics (E&E) technician will be needed to perform the pressure check.

Sheet metal technicians determine the canopy must be changed. They inform the Expediter and order the canopy. The Expediter has the weapons load crew safe the gun and download the munitions. This is a rather routine process and everything goes as expected. The Expediter checks with the MOC to determine a hangar location for the canopy change. Without waiting for the load crew to finish, the Expediter orders the tow

operation preparation and requests the egress technicians and the canopy hoist meet the aircraft at the hangar.

Once the weapons are clear, the tow begins and the aircraft is quickly pushed into the waiting hangar. Egress arrives with a new canopy, already built up from the shop. They safe the seat and remove the canopy. While in the middle of lowering the old canopy, the Specialist Expediter drives up and tells the egress technician that he is needed for a red ball foreign object damage (FOD) in the cockpit on another aircraft. The Specialist Expediter calls the Expediter to inform him of the actions and suggests two possible alternative egress technicians that are on duty. The Expediter locates another egress technician and gets him to pickup where the other left off. The reinstallation and longeron check occur without any problems. No cure time is needed because they were able to use a previously built up canopy so the aircraft is ready for pressure testing. The Expediter had previously called for the pressurization cart and it is already waiting at the aircraft. He now calls for the E&E tech to pressure check the aircraft. E&E get everything set up and begin the pressure test, however the internal pressure gauge is not moving. They flag down the next vehicle with a radio and report the situation to the Expediter. The Expediter arranges for a new pressure cart and the pressure check is completed with no discrepancies.

6 Scenario 3: Engine Prop Damage – Airlift (Tail #89-0448)

In the preflight inspection the Crew Chief discovers the #3 engine prop is not serviceable.

When the Expediter arrives at the aircraft, he calls the engine technician to begin looking into the problem. The Expediter knows that in the worse case the prop will need to be changed. This will require a new prop, an empty prop dolly, a heavy lift crane, a prop change crew, a B1 stand and finally an engine run which will require a power unit, an engine run crew (could be the same people as the prop change crew) as well as a take-off rated thrust (TRT) rated parking spot to perform the run. They will also need a tow vehicle, tow bar and tow team to get the aircraft to the TRT spot.

The Expediter orders the B1 stand, the prop dolly and crane while the engine technicians order the prop. The crane is positioned and the prop change crew begins

lowering the prop. As the crane is lowering the prop, a hydraulic line on the crane begins to leak. The prop is lowered safely, but now the crane is not operable. The old prop is transferred to the dolly and returned to the shop. The crane is a unique asset and they only brought one of them. Vehicle maintenance can repair the crane, but it will take them about two hours to do so. The Expediter knows that the fighter AMU possesses a cobra crane for work on canopies and seats. This crane is no where near as strong as the heavy lift crane they were using, but strong enough to lift the prop. The Expediter calls the MOC to coordinate the use of the crane.

The crane arrives and the prop is installed. After the installation is complete the aircraft needs to be towed to the TRT site for a full engine run. The tow tractor and tow team are assembled and the aircraft is towed. The aircraft is positioned and the run crew is assembled. As they obtain clearance for the run, the MOC calls the Expediter telling him that one of his engine run people has an emergency at home. They have just received a Red Cross message and he needs to be on the next flight headed back to the states. The engine technician is returned to his hotel room and the Expediter begins looking for another engine run qualified technician. Eventually, a Crew Chief with the required qualification is located and the run begins. The TRT engine run is completed and the aircraft is returned to operational status.

7 Scenario 3: Engine Compressor Stall – Fighter (Tail #85-1464)

During an 80% engine run for scheduled maintenance, the engine exhibited a series of loud compressor stalls. This aircraft is on toady's flying schedule. The Expediter knows that in the worse case the engine will need to be changed. This will require a new engine, a 3000 trailer, an engine change crew, a structural repair technician to perform the engine bay inspection prior to installing the new engine, and finally an engine run which will require a power unit, an engine run crew (could be the same people as the engine change crew) as well as the trim pad to perform the run. Also required will be the weapons load crew to safe the aircraft and possibly download the weapons.

Upon troubleshooting, the engine technicians discover a fuel flow regulator has failed. This change will require a rather simple fix, but will necessitate an afterburner run after the regulator is changed. The Expediter has the weapons load crew safe the gun and

download the munitions. This is a rather routine process and everything goes as expected. The engine technicians order the regulator. Once the weapons are clear, the Crew Chief begins opening the panels required for the regulator change. While doing so, he strips a screw and needs structural repair to assist in removing the screw.

The structural repair technician needs a low pressure cart (Low pack) in order to complete the job. The Expediter checks the ready line and collects the low pack and delivers it to the aircraft. The structural repair technician was just getting started when the first sergeant came out and pulled him off the job. The squadron had received a Red Cross message explaining that his little girl was quite sick and his presence was requested back home. A structural repair technician is pulled from the other aircraft and makes the required repairs and the new regulator is installed. After the installation is complete the aircraft needs to be towed to the trim pad for a full after burner (AB) power engine run. The tow tractor and tow team are assembled but the tow bar is missing. The unit deployed more tow tractors than tow bars as the tractors are used for towing more than just aircraft. Eventually the Expediter finds a tow bar near the hangar and the tow is allowed to proceed. The aircraft is appropriately secured and the run crew is assembled. The AB engine run is completed and the aircraft is returned to operational status.

8 Scenario 4: Fuel Leak – Airlift (Tail #89-0447)

The Crew Chief discovers fuel leaking from the wing root area. The leak is not bad and has not created a fuel spill. Fuels technicians use a quick access panel to determine the leak is beyond limits and the transfer valve must be changed. Prior to changing the valve, the aircraft fuel level must be brought below the level of the valve and the aircraft must be towed into the fuel cell. Since the valve is external to the tank, tank entry will not be required. After the valve is changed, the aircraft must again be towed, fuel brought back up to the appropriate level for the check and then a leak and transfer check must be performed. Needed for this job will be the fuels technician, the tow bar, tow tractor, tow crew, a low pack to aid in depaneling the aircraft, and when the aircraft returns to the flightline, a power unit and a light cart will be needed for the leak and transfer checks which will likely occur during hours of darkness.

The fuels technician provides configuration requirements for the aircraft to the Expediter and returns to the fuel cell (shop) to order the part. The configuration requirements include (among other things) depaneling the wing root as well as disconnecting the battery. Two Crew Chiefs are working the configuration checklist, one removing the requisite panels and the other doing the other prep work. While disconnecting the batteries, the Crew Chief somehow shorts out the battery which results in minor burns on the Crew Chief's hands. The Specialist Expediter was driving by at the time and takes the injured Crew Chief to the hospital. The other Crew Chief notifies the Expediter who reports the incident to the MOC and begins to look for a replacement Crew Chief to complete the job. The battery condition will be evaluated when the aircraft returns to the flightline. The new Crew Chief arrives and the configuration checklist is completed. The Expediter organizes the tow crew and ensures the tow tug and tow bar are available. The aircraft is towed to the fuel cell and the work is done quickly. Once the job is complete, the fuel cell notifies the MOC to let the Expediter know to return the aircraft to the flightline. The Expediter ensures the tow equipment and crew head back to the fuel cell and the aircraft is returned to the line in short order. The Crew Chief inspects the battery and it appears to be serviceable and power on confirms that it was undamaged. The leak and transfer checks begin. The leak check seems to be good, but the Hobart power unit, used to provide the power needed to perform the transfer check, keeps kicking the circuit off-line. Hobarts have a tendency to not work properly with certain airplanes and this particular one and aircraft 447 do not seem to get along. A new Hobart is needed. The new Hobart arrives and seems to work properly with the aircraft systems. The leak and transfer checks work properly and the aircraft returns to fully mission capable status.

9 Scenario 4: Fuel Leak – Fighter (Tail #85-1463)

While performing preflight inspections, the Crew Chief discovers fuel leaking from the wing root area. The leak is not bad and has not created a fuel spill. Fuels technicians use a quick access panel to determine that the leak is beyond limits and the transfer valve must be changed. Prior to changing the valve, the aircraft fuel level must be brought below the level of the valve and the aircraft must be towed into the fuel cell. After the valve is changed, the aircraft must again be towed, fuel must be brought back up to the

appropriate level for the check and then a leak and transfer check must be performed. Needed for this job will be the fuels technician, the tow bar, tow tractor, tow crew, a low pack to aid in depaneling the aircraft, and when the aircraft returns to the flightline, a power unit, a C-10 air conditioner and a light cart will be needed for the leak and transfer checks which will likely occur during hours of darkness.

The fuels technician provides a configuration checklist for the aircraft to the Expediter and returns to the fuel cell (shop) to order the part. The configuration requirements include depaneling the wing root as well as disconnecting the battery and other preparatory work. Two Crew Chiefs are working the configuration checklist, one removing the requisite panels and the other doing the other prep work. While disconnecting the battery, the Crew Chief somehow shorts out the battery which results in minor burns on his hands. The Specialist Expediter was driving by at the time and takes the injured Crew Chief to the hospital. The other Crew Chief notifies the Expediter who reports the incident to the MOC and begins to look for a replacement Crew Chief to complete the job. The battery condition will be evaluated when the aircraft returns to the flightline. The new crew Chief arrives and the configuration checklist is completed. The Expediter organizes the tow crew and ensures the tow tug and tow bar are available. The aircraft is towed to the fuel cell and the work is done quickly. Once the job is complete, the fuel cell notifies the MOC to let the Expediter know to return the aircraft to the flightline. The Expediter ensures the tow equipment and crew head back to the fuel cell and the aircraft is returned to the line in short order. The Crew Chief inspects the battery and it appears to be serviceable and power on confirms that it was undamaged. The leak and transfer checks begin. The leak check seems to be good, but the -60 power unit used to provide the power needed to perform the transfer check, is not putting out enough bleed air to properly drive the C-10. The C-10 is to provide auxiliary cooling for the avionics and electrical systems when the aircraft air conditioner is not operating. A new -60 is needed. The new -60 arrives and seems to work properly with the aircraft systems. The leak and transfer checks work properly and the aircraft returns to fully mission capable status.